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**MCDONNELL DOUGLAS ASTRONAUTICS COMPANY**

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# POWER EXTENSION PACKAGE (PEP) SYSTEM DEFINITION EXTENSION

Orbital Service Module Systems Analysis Study

VOLUME 10  
PEP Project Plan

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## PREFACE

The extension phase of the Orbital Service Module (OSM) Systems Analysis Study was conducted to further identify Power Extension Package (PEP) system concepts which would increase the electrical power and mission duration capabilities of the Shuttle Orbiter. Use of solar array power to supplement the Orbiter's fuel cell/cryogenic system will double the power available to payloads and more than triple the allowable mission duration, thus greatly improving the Orbiter's capability to support the payload needs of sortie missions (those in which the payload remains in the Orbiter).

To establish the technical and programmatic basis for initiating hardware development, the PEP concept definition has been refined, and the performance capability and the mission utility of a reference design baseline have been examined in depth. Design requirements and support criteria specifications have been documented, and essential implementation plans have been prepared. Supporting trade studies and analyses have been completed.

The study report consists of 12 documents:

- Volume 1 Executive Summary
- Volume 2 PEP Preliminary Design Definition
- Volume 3 PEP Analysis and Tradeoffs
- Volume 4 PEP Functional Specification
- Volume 5 PEP Environmental Specification
- Volume 6 PEP Product Assurance
- Volume 7 PEP Logistics and Training Plan Requirements
- Volume 8 PEP Operations Support
- Volume 9 PEP Design, Development, and Test Plans
- Volume 10 PEP Project Plan
- Volume 11 PEP Cost, Schedules, and Work Breakdown Structure Dictionary
- Volume 12 PEP Data Item Descriptions

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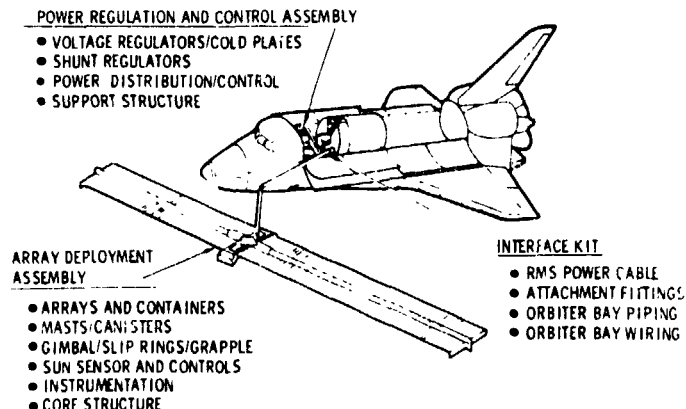
## FOREWORD

The Power Extension Package (PEP) is a solar electrical power generating system to be used on the Shuttle Orbiter to augment its power capability and to conserve fuel cell cryogenic supplies, thereby increasing power available for payloads and allowing increased mission duration. The Orbiter, supplemented by PEP, can provide up to 15 kW continuous power to the payloads for missions of up to 48 days duration.

When required for a sortie mission, PEP is easily installed within the Orbiter cargo bay as a mission-dependent kit. When the operating orbit is reached, the PEP solar array package is deployed from the Orbiter by the remote manipulator system (RMS). The solar array is then extended and oriented toward the sun, which it tracks using an integral sun sensor/gimbal system. The power generated by the array is carried by cables on the RMS back into the cargo bay, where it is processed and distributed by PEP to the Orbiter load buses. After the mission is completed, the array is retracted and restowed within the Orbiter for earth return.

The figure below shows the PEP system, which consists of two major assemblies -- the Array Deployment Assembly (ADA) and the Power Regulation and Control Assembly (PRCA) -- plus the necessary interface kit. It is nominally installed at the forward end of the Orbiter bay above the Spacelab tunnel, but can be located anywhere within the cargo bay if necessary. The ADA, which is deployed, consists of two lightweight, foldable solar array wings with their containment boxes and deployment masts, two diode assembly interconnect boxes, a sun tracker/control/instrumentation assembly, a two-axis gimbal/slip ring assembly, and the RMS grapple fixture. All these items are mounted to a support structure that interfaces with the Orbiter. The PRCA, which remains in the Orbiter cargo bay, consists of six pulse-width-modulated voltage regulators mounted to three cold plates, three shunt regulators to protect the Orbiter buses from overvoltage, and a power distribution and control box, all mounted to a support beam that interfaces with the Orbiter.

PEP is compatible with all currently defined missions and payloads and imposes minimal weight and volume penalties on these missions. It can be installed and removed as needed at the launch site within the normal Orbiter turnaround cycle.



#### ACKNOWLEDGMENT

During the OSM study extension McDonnell Douglas Astronautics Company had the active support of the following organizations, independently funded by NASA, in support of the PEP definition:

Rockwell International - Orbiter interfaces

Lockheed Missiles and Space - Solar array

TRW Systems Group - Solar array

In addition, Spar Aerospace Products, Ltd., participated as an MDAC subcontractor in defining remote manipulator system modifications and dynamics, and European Space Agency/European Research National Organization provided detail data on Spacelab design/utilization.

MDAC wishes to acknowledge the significant contribution of these organizations in support of the PEP Project.

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## Section 1

### INTRODUCTION

With the advent of Space Transportation System (STS) operations, a new era of space exploration and use will begin. A multiplicity of payload types ranging from material processing to astronomical experiments will be transported to and from orbit. Many of the payloads will remain attached to the Orbiter during their entire missions and will fly in an Orbiter sortie or Orbiter/Spacelab sortie mode.

An extensive analysis of the STS Traffic Model and projected user activities indicates the need for electrical power services to the payloads that significantly exceeds the resource capabilities of the Orbiter in terms of power level and duration. The need for these services has been confirmed by the life sciences, materials processing, astronomy, solar observation, earth observation, and related scientific communities.

The Orbiter, with a fuel cell/cryogenic electrical power system, can only provide experiment payloads with 7 kW for 5 to 6 days in the Orbiter sortie mode and 2.5 kW for 5 to 6 days in the nominal Orbiter/Spacelab sortie mode.

With the addition of the PEP, the Orbiter can provide experiment payloads up to 15 kW and 48 days mission duration in the Orbiter sortie mode. The result is more than a fourfold increase of power service capability to payload users.

The PEP consists of a solar array and an electrical conditioning package that is stowed in the Orbiter bay. The solar array portion is deployed by the remote manipulator system (RMS) arm during orbital operations and, in conjunction with the Orbiter fuel cell/cryogenic electrical power system, provides increased continual electric power. The solar array is restowed in the Orbiter upon completion of the Orbital sortie and returns in the Orbiter to the launch site for reuse on the next needed mission.

The timing of development of PEP is based on its being available for early Spacelab flights. Its usage will span the total life of Orbiter operations and will regularly provide the needed missions with the required additional power.

This PEP Project Plan is the basic document which describes the overall plan for proceeding with developing PEP. It contains the information required for management control at the STS Program Office level as a project element of the STS Program. It emphasizes the management and programmatic aspects of the project rather than technical information. It will be developed more fully as the project proceeds into hardware development and will be updated and approved at that time.

The sections in this volume have been organized in accordance with NASA Management Instruction NMI 7121.16, dated 24 March 1977.

## Section 2

### PROJECT PLAN SUMMARY

This Project Plan provides the basis for developing and placing into operation the PEP as an element of the STS Program. The plan is based on developing two sets of PEP hardware so that the first set will be available for flight during the second quarter of 1983 and the second set during the fourth quarter of 1983 so the early Spacelab and subsequent missions are supported.

Since PEP is carried in the Orbiter cargo bay and operates in conjunction with the Orbiter and the RMS, the plan takes into account that design and programmatic interfaces will be closely maintained by the PEP Project element within the STS Program.

#### 2.1 GENERAL DESCRIPTION

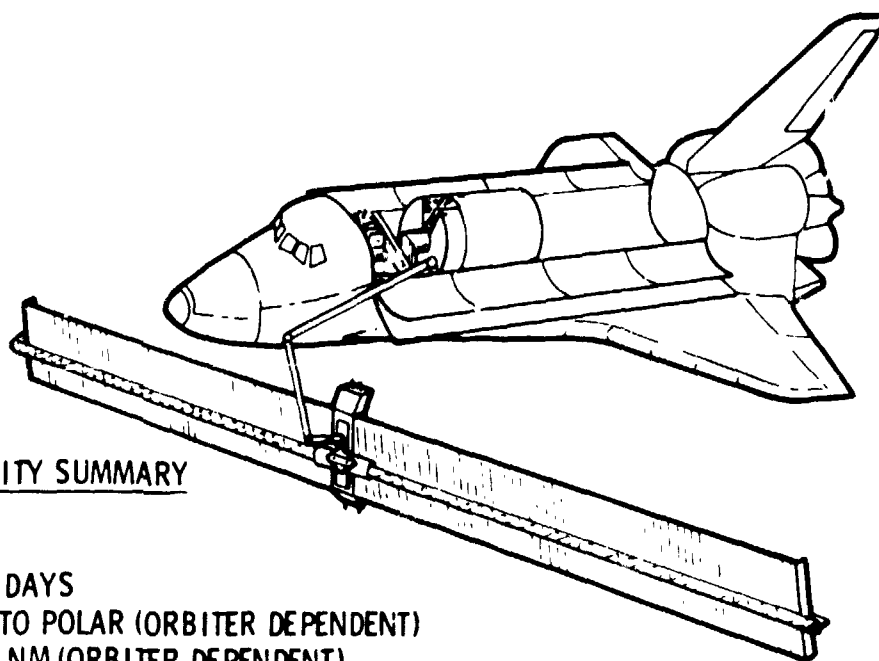
The PEP Project is a new element of the STS Program that will interface with the existing elements and use the basic STS support facilities and services at Johnson and Kennedy Space Centers as required. As currently planned, the major project milestones will be ATP on 1 October 1980, PEP 1 delivery to KSC on 15 February 1983, qualification flight/IOC on 1 April 1983, and PEP 2 delivery on 15 July 1983. The PEP system will be developed by a prime contractor under the direction of the PEP Project Office at JSC. The solar array hardware will be a major subcontract to the prime contractor. The RMS modifications will be a major subcontract to the prime contractor or a combination of prime contractor and major subcontractor work. The Orbiter accommodations will be performed by the Orbiter contractor, who will also provide support to the PEP system contractor's interface activities in an associate contractor relationship. The RMS accommodation provisions will be accomplished by the RMS contractor.

The ATP for the prime contractor, major subcontractor, and Orbiter and RMS contractors representing all the major elements of the PEP Project is assumed to be 1 October 1980. This approach is deemed to be most cost- and schedule-effective and is based on assuming selection of the prime contractor on 1 July

1980, followed by appropriate negotiations and letter contracts for the major project elements on 1 October 1980.

The PEP system hardware referenced configuration consists of the array deployment assembly (ADA), the power regulation and control assembly (PRCA), and the interface kit hardware. Two sets of this flight hardware, along with two sets of GSE and one set of initial spares, will be provided for operational use.

In the operational mode, the PEP solar arrays will provide most of the power while the Orbiter is in the sun, and the Orbiter fuel cell and cryogenic system will provide the power on the shaded side of the orbit. The combination of solar arrays and fuel cells provide a continuous capability of 29 kW at the bus. This results in 15 kW in the Orbiter sortie mode or 10.5 kW in the nominal Orbiter/Spacelab mode to the experiment payloads, which represents in excess of a fourfold increase in power level and duration over the basic Orbiter system capability. Figure 1 illustrates the PEP system in orbital operations. As indicated, the solar array portion of the ADA is deployed by the RMS while the PRCA remains in the Orbiter cargo bay and provides regulation and control of the generated electrical power.



#### CAPABILITY SUMMARY

- 29 kW, MAXIMUM
- DURATION - UP TO 20 DAYS
- INCLINATION -  $28.5^{\circ}$  TO POLAR (ORBITER DEPENDENT)
- ALTITUDE - 160 TO 300 NM (ORBITER DEPENDENT)
- ALL ATTITUDE CAPABILITY
- OPERATION - 1981 ON
- WEIGHT - 2,010 LB

Figure 1. PEP Configuration

In the stowed configuration, the PEP system hardware results in negligible loss of available payload volume. The trunnion fittings permit installation at numerous locations in the cargo bay. For Spacelab module missions, the PEP is stowed in the forward area between the airlock and the Spacelab. The ADA and the PRCA may be easily removed from the Orbiter when they are not needed for a mission or for maintenance. Installation, removal, and maintenance times do not add any serial time to the Orbiter ground operations.

The PEP system design approach is based on minimum design modifications to the existing Orbiter and RMS systems. The ADA and PRCA are attached in the Orbiter cargo bay using standard cargo bay bridge fittings (lightweight bridge fittings are optional). The RMS connection to the solar array is made through a standard grapple connection.

No problems of technical feasibility have been identified to date and none are anticipated inasmuch as the basic system is predicated upon current technology and hardware already under development. Pre-ATP work on research and technical objectives and planning (RTOP) is being accomplished to assure that long-lead development items are clearly defined for proceeding into Phase C/D. The items include the voltage regulator, the gimbal assembly, and the solar cell assembly items.

## 2.2 PROGRAMMATICS SUMMARY

PEP Project schedule and funding is summarized in Figure 2. The figure shows the major milestones and funding required, based on the PEP reference configuration for budgetary planning purposes.

As indicated, the PEP system studies are to be completed during FY 79, followed by JSC RTOP's for selected technology areas to be accomplished before PEP ATP. A representative RFP procurement cycle is shown with the major milestones indicated, keyed to a 1 October 1980 PEP Phase C/D ATP.

Phase C/D activity is displayed for the PEP system effort, including the solar array and the Orbiter and RMS accommodations efforts indicating a 30-month period from ATP to PEP initial operational capability on 1 April 1983. This plan provides two sets of PEP system hardware and Orbiter and RMS accommodations with hardware deliveries scheduled for 15 January 1983 and 15 July 1983, respectively.

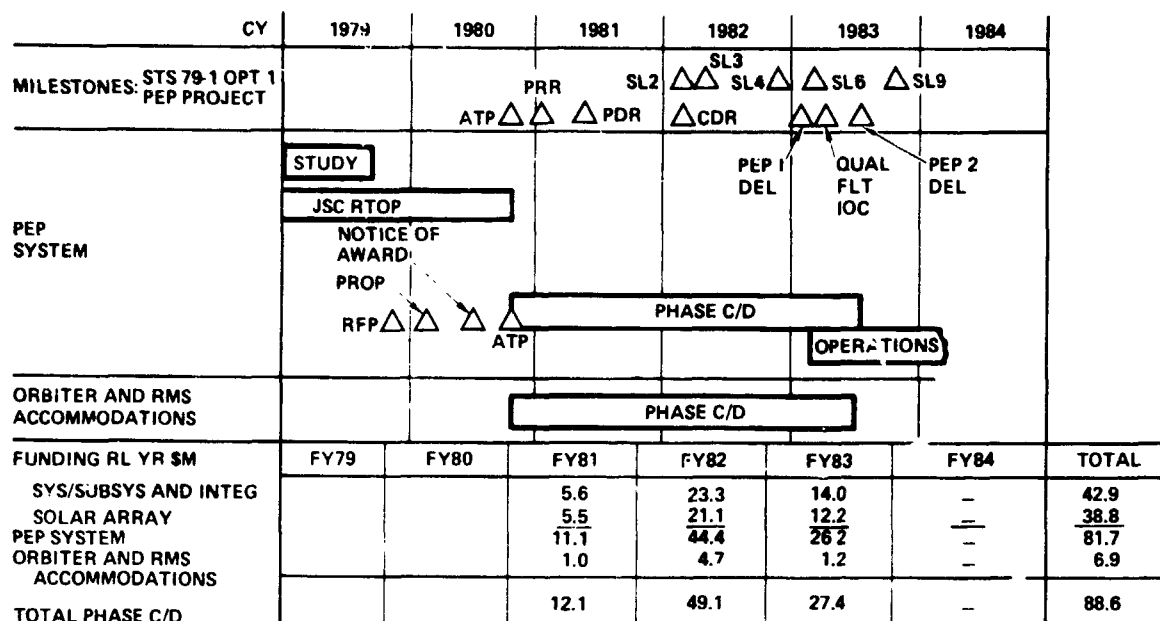


Figure 2. PEP Project Schedule and Funding (Reference Configuration Planning Baseline)

The corresponding Phase C/D funding is shown by fiscal year and cumulative total in real year dollars. PEP system funding is further subdivided to show the solar array element funding because of its magnitude. This funding plan reflects a relatively modest FY 81 funding requirement of \$12M with substantial funding not required until FY 82 and 83, consistent with the offload of funding from the basic Shuttle development program.

The programmatic analyses has resulted in establishment of the following key points, which are reflected in this reference configuration planning baseline:

- A. Current design/program issues are being resolved through RTOP.
  - Power conditioning.
  - Solar cells.
  - Gimbal/slip rings.
- B. Solar array definition emphasis is on low cost, i.e., low-cost cells.
- C. Interface with Orbiter and RMS has been established.
- D. Flight qualification will be used to minimize cost and verify IOC.
- E. Schedule and funding constraints have been taken into account:
  - Two PEP units.
  - Low first-year funding.

- 30 months to IOC.

- Second PEP unit available for 1984 WTR operations.

F. Critical path schedule items have been identified and taken into account in schedule planning.

In summary, the programatics have been defined and verified to a level of detail consistent with proceeding into the hardware development phase of the project.

### Section 3

#### PROJECT AND MISSION OBJECTIVES

The Shuttle, as part of the STS, will provide low-cost, high-payload-weight delivery capability to low earth orbit. The current and planned capability of the Orbiter to support these payloads is limited to about 7 kW to the payload for a mission duration of from 5 to 6 days. The PEP will provide the mechanism for realizing the full capabilities of Shuttle by augmenting the electrical power and mission duration provided. The capability offered by PEP is 15 kW to the payload with mission durations of up to 48 days.

The objective of PEP as part of the STS Program plan is to ensure that the foregoing capabilities are provided as needed. Furthermore, it is the intent that this development be accomplished in a manner to benefit other related developments, such as solar electric propulsion (SEP) and power module, by virtue of related technology items, design commonality, and flexibility of application.

#### 3.1 POWER AND DURATION CAPABILITY

The primary objective of the PEP Project is to provide the mechanism for significantly augmenting the Orbiter power and duration capability. On the current Orbiter, electrical power is provided by three fuel cells which convert  $H_2$  and  $O_2$  cryogenics to electrical energy. The long-term power offered to payloads is limited to 7 kW and the cryogen tankage limits the mission duration to 5 to 6 days. Additional cryogen kits ( $H_2$  and  $O_2$ ) placed under the payload bay liner or within the bay payload envelope would have provided only limited-duration extension capability at significant payload penalties. These techniques have been discarded recently as potential candidates for energy augmentation.

PEP provides additional electrical power by virtue of its deployable  $146-m^2$  solar array operating through PEP-provided regulation and distribution equipment to the Orbiter electrical bus. The total power provided is 29 kW, thus allowing 15 kW for payloads (14 kW is consumed by the Orbiter). The power gen-



eration scenario is then as follows: the Orbiter fuel cells provide the power when the orbit is in the shade. In the sun, the fuel cells are regulated back to an idle level of 3 kW (1 kW each) and the solar array provides 26 kW for a total of 29 kW. The mission duration is still limited by cryogen consumption but is increased because of the lower consumption at fuel cell idle. The cryo-gen consumption is effected by the amount of sunlight seen on a particular mission, and the duration is then a function of orbit inclination, altitude, time of year, time of day of launch, etc. The envelope of capability offered by PEP is shown in Figure 3 for various inclinations. The baseline Orbiter cryo-only capability is shown for reference. The full range of PEP performance capabilities is discussed in Section 3 of Volume 2.

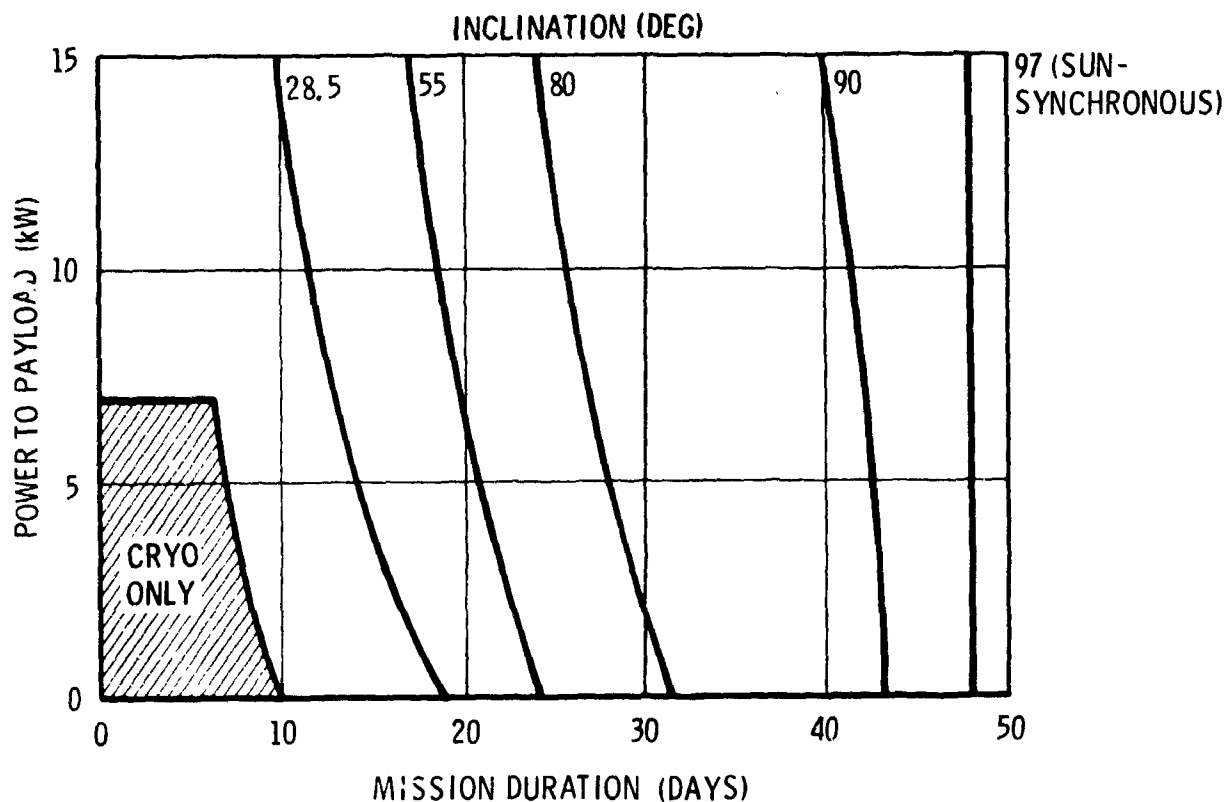


Figure 3. PEP Performance Envelope (4 Cryo Tank Sets, 3-kW Fuel Cell Idle, 220NM)

### 3.2 EARLY DEVELOPMENT NEED

A review of currently scheduled and planned Shuttle Sortie missions (i.e., Spacelab) indicates a great need for increased power and duration capability. This need is manifested, in fact, by the requirements for Spacelab Missions 1 through 5, which are all in need of additional power and/or duration capability. In addition, a commitment for PEP is needed early to ease the mission and

payload planning activities now proceeding such that they could take advantage of this emerging capability. Current plans are for PEP Phase C/D ATP on 1 October 1980, with delivery of the first two units on 15 February 1983 and 15 July 1983. First flight is scheduled for 1 April 1983.

### 3.3 SYSTEM COMMONALITY

An additional objective of the PEP project is to develop PEP with an eye toward component use on related future programs. The relation between PEP and SEP, power module, and the satellite service center requirements will be frequently and carefully reviewed to ensure that cost-effective steps toward common design elements are taken. These might include portions of the solar array, deployment mechanisms, power regulation and conditioning equipment, and distribution equipment.

## Section 4

### RELATED STUDIES AND TECHNOLOGY SUPPORT ACTIVITIES

#### 4.1 RELATED STUDIES

Studies directly supportive or closely related to PEP are listed in Table 1. The five current studies are all scheduled to be documented by 31 August 1979 and will thus provide detail data to assist NASA in RFP preparation; they will also, in all probability, highlight areas worthy of further support prior to C/D contract award. The two proposed studies are not expected to be funded until late this year; however, they may be expected to provide supporting data through PEP program requirements review, which is planned for January 1981.

#### 4.2 NASA TECHNOLOGY SUPPORT

JSC has submitted to NASA Headquarters for approval a power system engineering RTOP which collects tasks in several critical technology areas. Completion of these tasks, listed in Table 2, during CY 79 and 80 will provide reasonable assurance that all currently identified long-lead technology required for PEP is in hand.

Table 1. PEP Related Studies

Title (Contract)	Expected Product
OSM System Study PEP Definition Extension (NAS9-15532, JSC/MDAC)	Provides a PEP baseline definition to the Phase B level, including programmatic requirements.
PEP Solar Array Study (NAS9-15870, JSC/TRW)	Provides a PEP solar array/container definition and preliminary programatics.
PEP Solar Array Study (NAS9- , JSC/LMSC)	Provides a PEP solar array/container definition and preliminary programatics.
Solar Array Study (NAS8- , MSFC/TRW)	Provides an assessment of potential commonality of arrays for PEP/OSM/SEPS.
Solar Array Study (NAS8-32928, MSFC/LMSC)	Provides an assessment of potential commonality of arrays for PEP/OSM/SEPS.
OSM Phase B (TBD, MSFC/TBD)	RFP not out--to provide Phase B definition of free-flying OSM.
SEPS Phase B (TBD, MSFC/TBD)	RFP out--to provide Phase B definition of SEP system.

Table 2. PEP Supporting RTOP's

Code	Title	Expected products
906-51-XX	PEP system definition completion	PEP fuel cell interfaces/performance PEP/RMS/Orbiter interfaces
906-51-11	PEP solar array definition/design	Assess maintenance and repair approaches for solar array.
906-51-13	PEP power conditioning evaluation	Assess fuel cell/voltage regulator performance interactions utilizing EPDC at JSC.
906-51-14	PEP/RMS dynamic analysis	Assess Orbiter/PEP dynamic bounds. Define Orbiter/PEP software requirements and constraints.
906-51-15	PEP solar cell development	Implement and qualify a wraparound solar cell production line for PEP.
906-51-16	PEP rotating gimbal	Define requirements and characteristics. Procure prototype slip ring assembly for PEP.
906-51-18	PEP solar array systems analysis software	Determine modeling requirements for and develop simplified models of PEP/Orbiter solar array performance.
906-51-XX	Augmented Orbiter heat rejection study	TBD
906-51-XX	Enhanced Orbiter CO <sub>2</sub> removal system	TBD
906-51-XX	Resource summary	TBD

## Section 5

### TECHNICAL SUMMARY

This section summarizes the technical aspects of the project. Emphasis has been placed on the key elements involved in achievement of the project objectives. The significant areas of emphasis discussed in the following subsections are Missions, Systems, Design Development, Facilities, Logistics, and Ground and Flight Operations. Included is the rationale which will be the basis for subsequent detail planning.

#### 5.1 MISSIONS

The mission of PEP is to augment the power and duration capability of the Orbiter for sortie missions. These would be primarily Spacelab module and pallet missions and also include combined missions and extended delivery missions. PEP doubles the power offered to payloads (15 kW) and increases the duration capability from a nominal of 6 to a maximum of 48 days. It can accommodate all Orbiter missions, i.e., 28.5 to 104-deg inclination and 100 to 600-nm altitude. This added capability would eliminate the energy shortages present on the first scheduled Spacelab missions. The first five are energy-short, based on their current payloads, and following missions already require additional energy in their planning stages. In addition, PEP would allow fuller use of payload equipment and increased data-gathering capability. In addition, this added capability will allow the placement of additional payload equipment on a given flight and thus, in the long term, decrease the number of flights needed.

#### 5.2 SYSTEMS

The PEP system constitutes an independent power subsystem which interfaces directly with the Orbiter power buses to provide regulated power (i.e., 32.6 VDC nominal) to both the Orbiter subsystems and payloads.

The PEP system elements to be considered in this technical plan include the following:

### 5.2.1 PEP Flight Hardware

A. ADA, which consists of the solar array boxes, blankets and array equipment, masts with canisters, two-axis gimbal system, sun sensor, signal processor, and the strongback support structure.

B. PRCA, which contains the voltage regulators, cold-plate installations, power cables, power-distribution box, and shunt regulators.

C. Interface kit, which includes bridge fittings, retention latches, power cables, and data/command harnesses.

### 5.2.2 Orbiter and RMS Accommodations

The PEP power cable installation on the RMS requires attachment of cable support brackets. The RMS accommodation provisions require modification of the RMS basic structure so that brackets can be permanently attached.

Modifications to the Orbiter have been defined by Rockwell International and defined in their Interface Definition Document, which was prepared jointly by RI and MDAC.

The two major end item assemblies, the ADA and PRCA, are installed in the Orbiter's cargo bay, as shown in Figure 4. During all PEP orbital operations, the PRCA reference configuration remains in the position shown. Conversely, the ADA is deployed from the Orbiter's cargo bay by the RMS for PEP operations.

An exploded view of the ADA is shown in Figure 5. It consists of two flexible blanket solar cell arrays, two coilable masts for deployment and retraction of each array wing, central support structure or strongback for mounting the array, auxiliary avionics equipment, and Orbiter attachment trunnions. The two independently deployed solar arrays are housed in separate box assemblies. For array deployment, the canisters are each rotated 90 deg until perpendicular to the blanket box assemblies. The ADA is supported in the cargo bay on trunnions and is restrained by remotely controlled latches. The ADA incorporates a grapple fixture which mates with the RMS end effector and a gimbal assembly which allows orientation of the array for sun-pointing at all Orbiter attitudes and orbital locations. PEP array pointing is controlled by a sun sensor and processor. The array power is transferred to the PRCA voltage regulator, via the power cable mounted on the RMS.

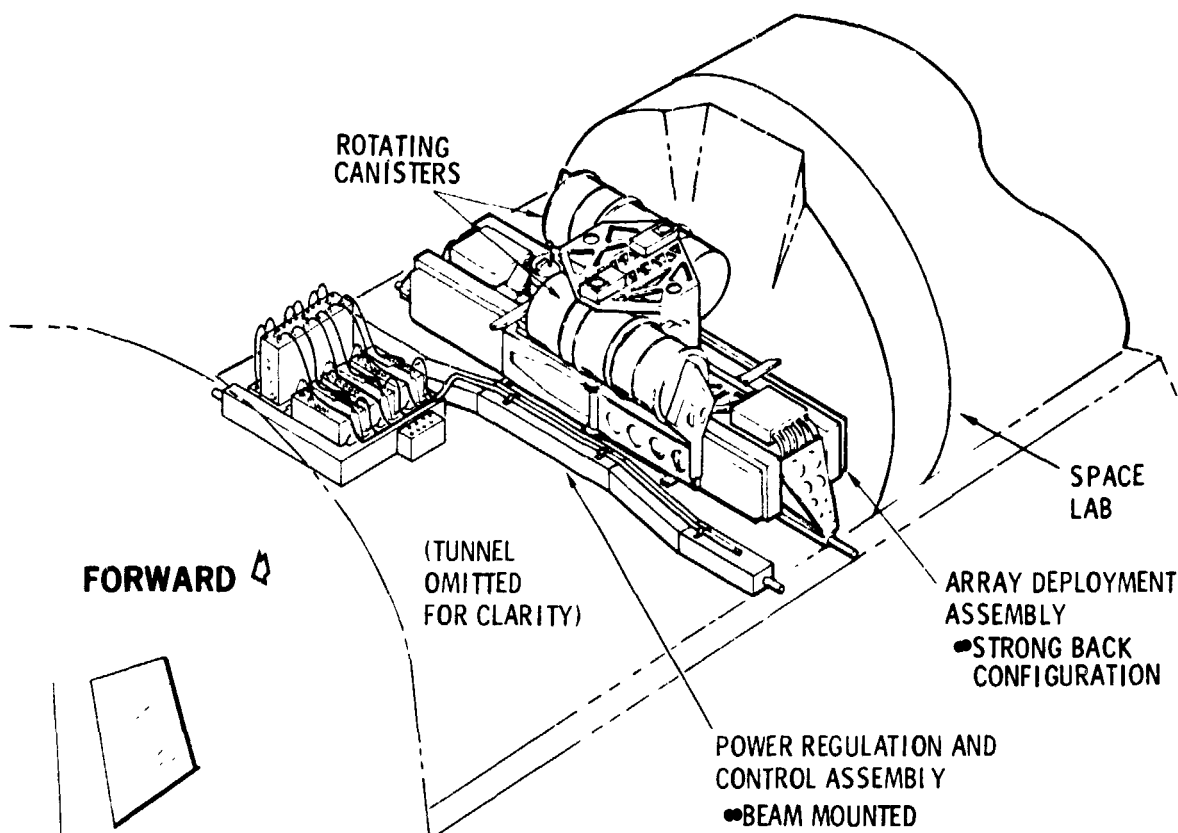


Figure 4. PEP Reference Installation (Two-Beam Configuration)

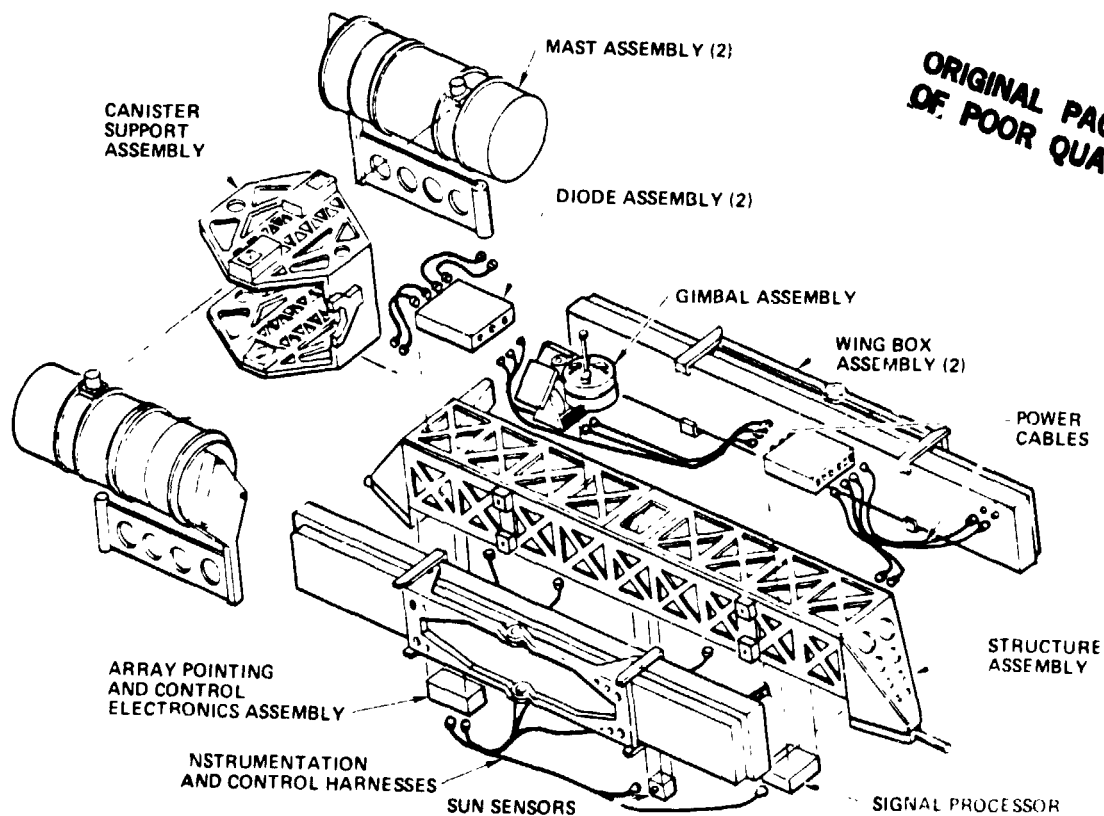


Figure 5. Array Deployment Assembly in Exploded View

The PRCA is shown in Figure 6. As noted, this assembly remains in the Orbiter bay and provides regulation and distribution of the array's electrical output for compatibility with the Orbiter buses. This is accomplished with six identical pulse-width-modulated regulators that are configured for parallel operation. The regulators reduce the relatively high voltage of the array down to 32.6 VDC within a 0.2-V band. This voltage range results in the desired load-sharing characteristics between solar array and the Orbiter fuel cells. The regulated power is transferred from the PRCA power-distribution box to the three Orbiter power buses. A cold plate is mounted between each of three sets of regulators to provide active cooling with circulating Freon from the Orbiter aft cold-plate loop.

In addition to mounting the PEP in the forward location in the volume between the airlock and the Spacelab module (reference Figure 4), the PEP can be used with Spacelab pallets, as shown in Figure 7. The PRCA, with the power-distribution box and voltage regulators, normally would be mounted in the forward location to minimize Orbiter scar weight and standardize the Orbiter interface; however, the ADA can be mounted at various fore and aft locations

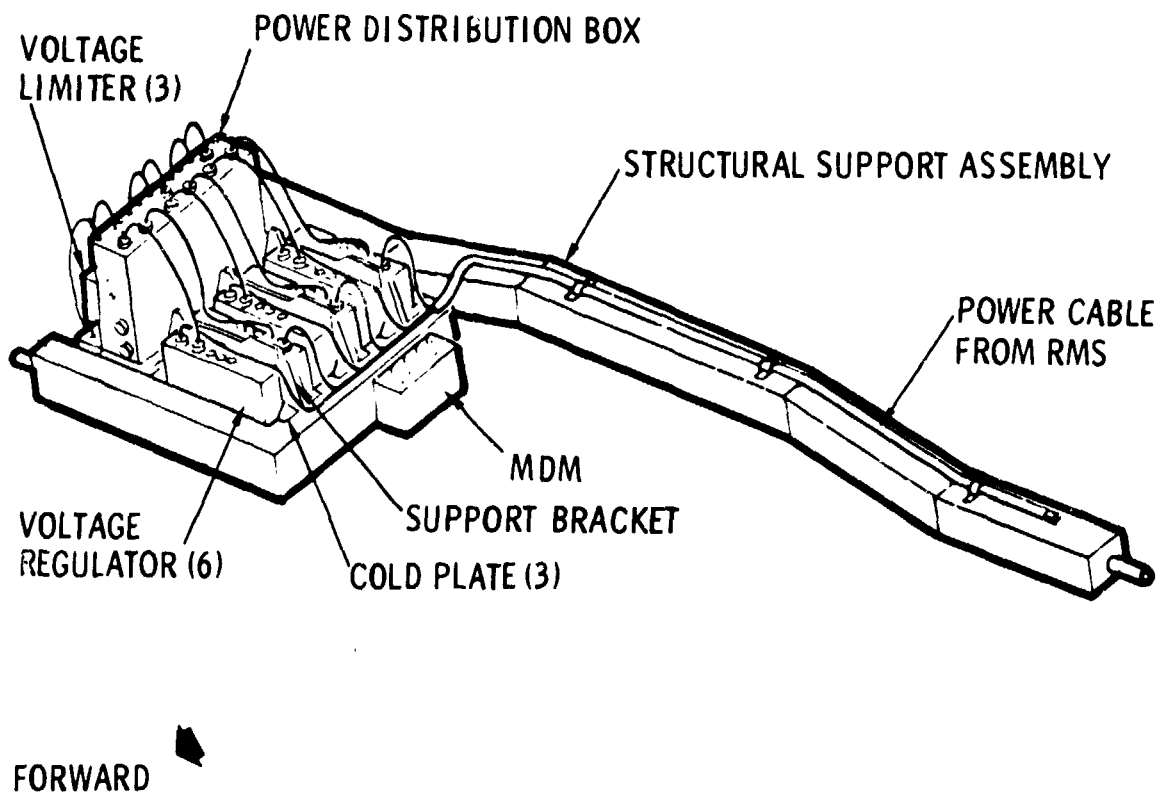


Figure 6. Power Regulation and Control Assembly



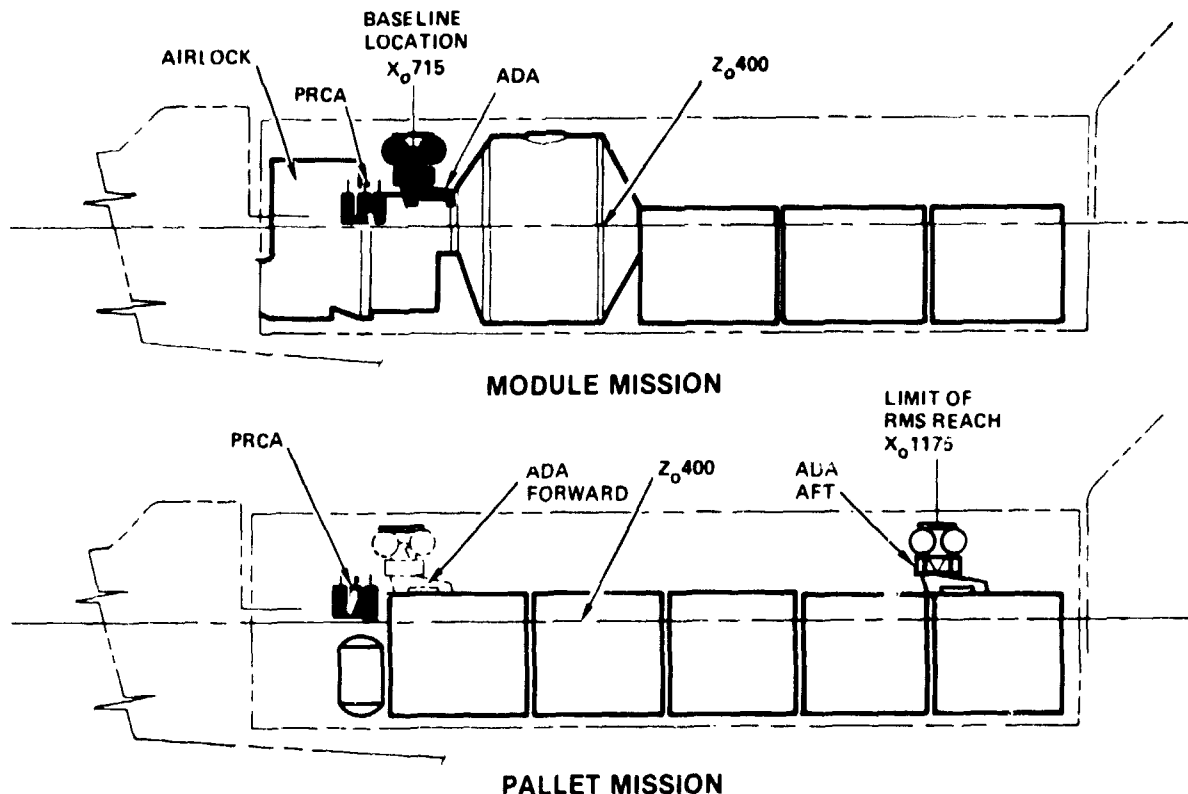


Figure 7. PEP Cargo Bay Installation Envelope

in the cargo bay. The RMS modifications and selected PEP power cable installation are shown in Figure 8. The major modification task is the mounting of the power cable support brackets on the RMS primary structure. These are bonded to the cylindrical beams and mechanically attached to the elbow's machined aluminum housings. This task must be accomplished at the subassembly level prior to final assembly or following disassembly of a built-up RMS. The power cable is removable in the field for non-PEP missions that require the RMS. For non-RMS missions, the RMS can be removed from the Orbiter after the PEP power cable has been removed.

### 5.3 DESIGN AND DEVELOPMENT

This section outlines the salient points of the approach planned for design and development of the PEP Project hardware. Emphasized are the PEP system prime contractor/subcontractor(s) technical roles and interfaces, and the design and test philosophy for the flight hardware. This information is based on Volume 9 (PEP Design, Development, and Test Plans), which should be referred to for additional information and supporting data.

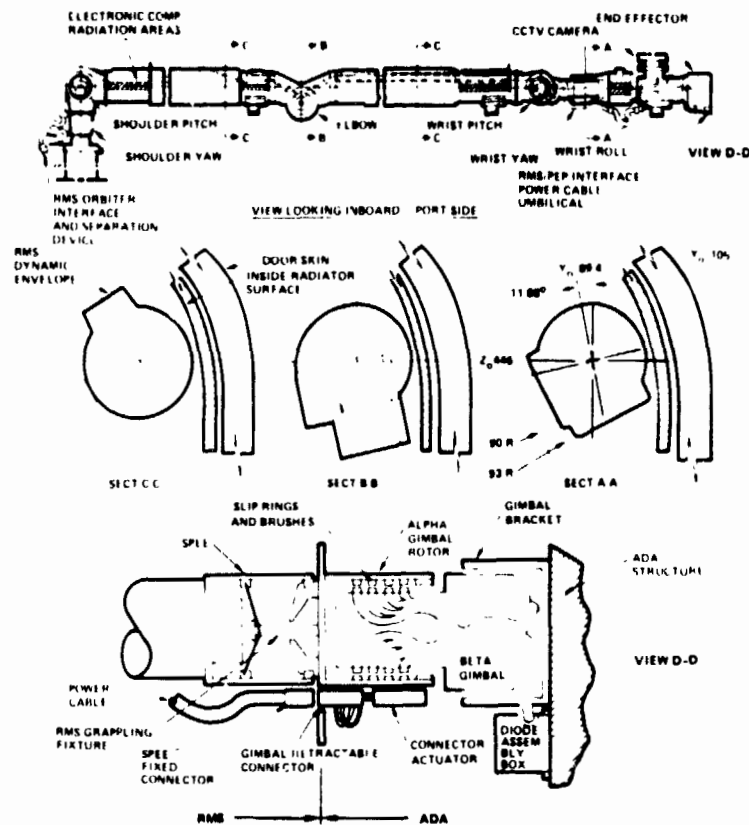
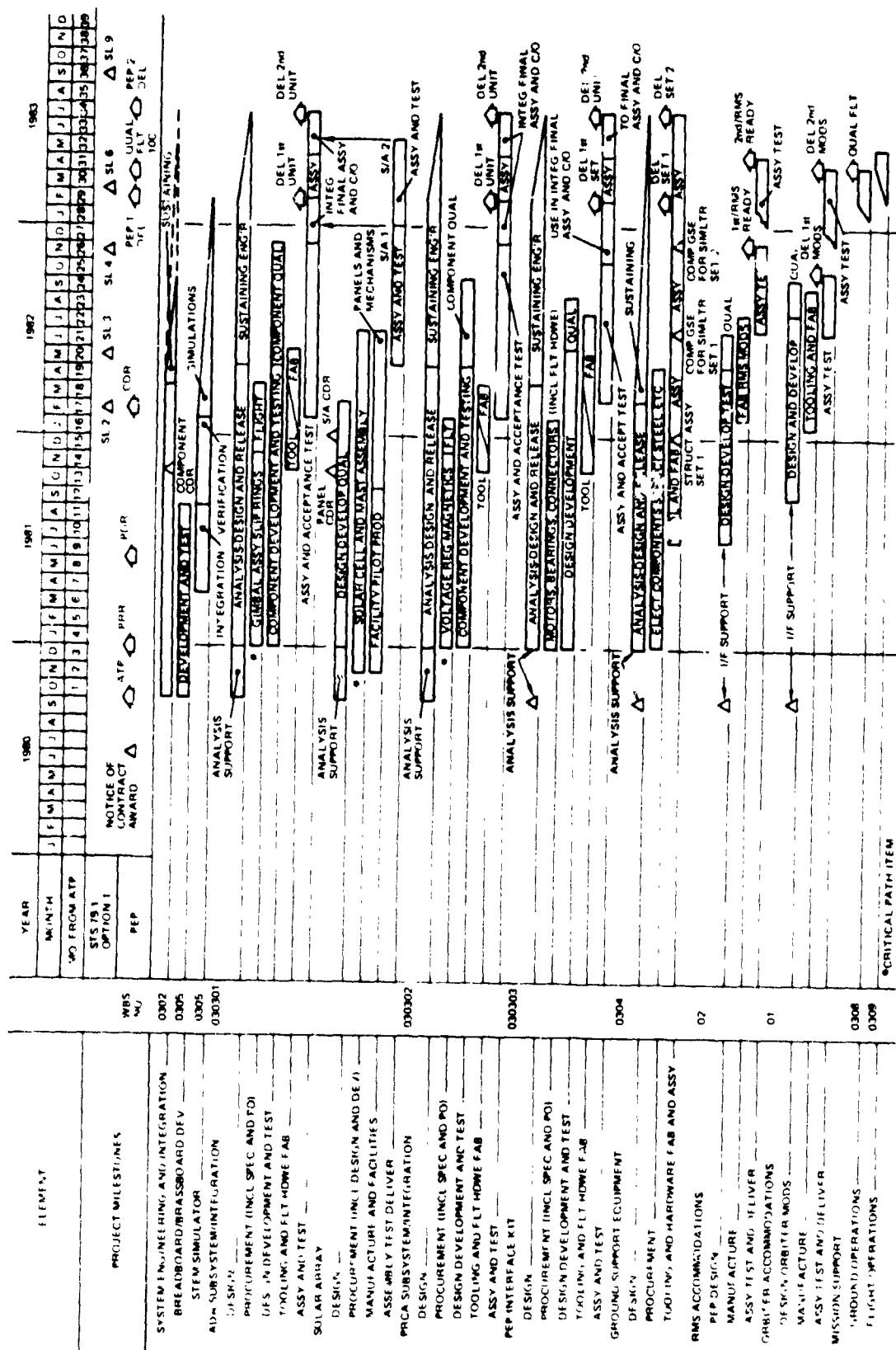


Figure 8. RMS Power Cable and Gimbal Schematic

Figure 9 presents the PEP baseline master schedule, which identifies major subassemblies, development tasks, period of performance, and major milestones. The design and development milestones call for a program requirement review 3 months after ATP and a preliminary design review 5 months later. The CDR occurs in the seventeenth month, with the first delivery of a PEP in the twenty-eighth month following ATP. The first flight for PEP, establishing the initial operational capability (IOC), occurs 30 months after ATP.

The prime contractor will do the system design of the ADA, manufacture the support structure for it, and integrate the total assembly. The solar array subcontractor will do the detail design and manufacturing of the solar array and deployment mechanisms, procure the masts, and deliver them to the prime contractor for assembly into the ADA and final acceptance testing.

Only the support structure interfaces with the Orbiter, i.e., physically in the Orbiter bay. PEP interfaces, both physically and functionally (avionics and data connectors), through the grapple fitting with the RMS. The subcontractor will qualify his deliverable flight hardware and equipment to the



**Figure 9. PEP Project Master Schedule**

highest level that is practical and consistent with a minimum risk, low-cost program development. The remaining qualification required of the ADA for first flight will be completed by the prime contractor.

The PRCA is supplied by the prime contractor. It is composed of fabricated parts and vendor-supplied components. The PRCA interfaces physically and functionally with Orbiter in the bay and functionally with the RMS via electrical connectors near the RMS shoulder. The functional connection between the ADA and PRCA is the power cable installed on the RMS between the shoulder and effector.

The PEP impact on the RMS is minimum, consisting only of the accommodation provisions of the aforementioned wire harness. The prime contractor will provide qualified wire cable to the RMS contractor for the development of the harness. The cable-mounted half of the electrical connectors will also be supplied by the prime contractor.

The Orbiter accommodations required by PEP for the design reference mission utilizing the Spacelab and tunnel are as follows: (1) none for the ADA, (2) a bearing pad on the starboard longeron to react to contact loads by the PRCA custom bridge, and (3) two wire harness installations from the PRCA to the Orbiter interface connector panels, one on each of the port and starboard sides of the Orbiter bay, and (4) a thermal control interface panel with inlet/outlet lines and two disconnect valves on each side of the cargo bay.

The design philosophy established for PEP is directed toward maximum crew/Orbiter safety, reliability, and maintainability consistent with sortie mission systems, and meeting the cost goals set for the development of the system. It is essential that the most economic approach, consistent with weight, performance, and safety requirements, be taken for all aspects of the project. Testing must be minimized but still complete enough to ensure verification that PEP meets design and performance requirements that cannot be verified by analyses or similarity comparison to existing qualified flight hardware. Further, test hardware produced solely for test purposes must be minimized. This development approach is reasonable because (1) PEP is inherently a safe system because it is used only to augment the existing electric power system, (2) failure of the PEP system during flight does not totally void an Orbiter sortie mission but only reduces its duration, and (3) the PEP is recovered after each mission and will undergo maintenance and repair as required.

The verification test and evaluation (VT&E) approach being planned for PEP will be similar to design evaluation and qualification testing successfully accomplished on past NASA programs but taking into account that system qualification will be accomplished by the first flight. The design qualification approach to testing will qualify a component or item of equipment during a development test if the test specimen is sufficiently representative of the flight article and is subjected to test levels that meet qualification test requirements without failure. Design qualification testing, together with evaluation and qualification of components and equipment by exhaustive analyses, and by similarity comparisons to qualified hardware in lieu of testing, provides the opportunity to develop PEP at the least possible cost while taking minimum technical risks.

VT&E will be done on the components and equipment and to the ADA and PRCA subsystem level in the development, qualification, and acceptance test program. The first flight of the ADA and PRCA integrated into PEP will complete system qualification and establish PEP IOC. In the interest of reducing costs, development and qualification testing will be combined on selected tests in accordance with the design qualification test philosophy. Acceptance tests will be those typical of production acceptance testing. However, for PEP acceptance, testing on all avionics components and equipment will include vibration and high-low thermal tests to ensure integrity of electrical connections.

During development a verification integration simulator for power and avionics will be used to develop and verify software and verify system operation and performance.

Figure 10 depicts the design development and test schedule for the PEP system through hardware delivery with respect to the design development milestones of the project.

#### 5.4 FACILITIES

The facilities required for engineering, development, qualification, production, and product acceptance of PEP are consistent with normal space hardware production. For the subcontract-level solar array development and production, existing facilities are in the process of being augmented by the prospective solar array contractor(s) and will be available for PEP by ATP. Along with the

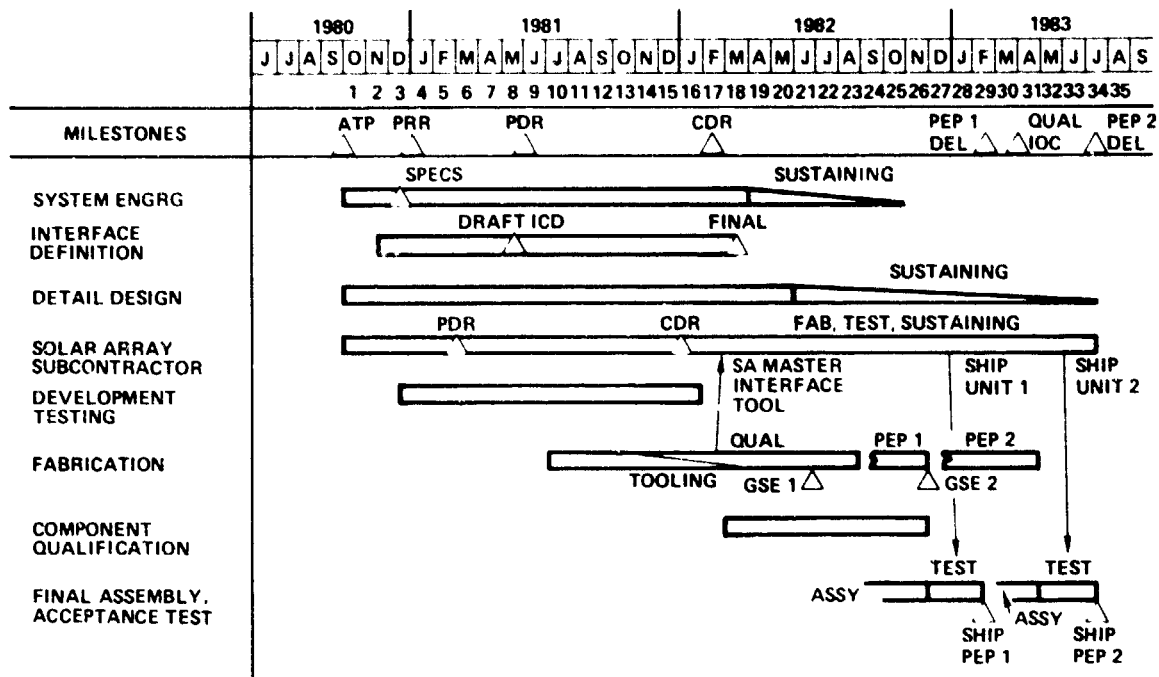


Figure 10. PEP Design, Development and Test Schedule

solar array facility preparation, the prospective solar cell suppliers are assessing production capacity requirements to assure that adequate production rates can be met for PEP.

Existing NASA facilities, including training and simulation testing, are adequate for NASA in-house activities. During the launch and flight operations phase, existing STS facilities will be used with essentially no modifications. For launch site processing, the plan will avoid full deployment of the solar arrays at the launch site which otherwise could require facility construction or modification. This facility capability will exist at the solar array subcontractor's location where such maintenance would be done. Flight and orbital activities in support of PEP come under the already-planned capabilities for the STS Program.

In summary, it is not anticipated that new facilities or facility modifications will be required for the PEP Project if existing facilities will be available as planned.

## 5.5 PEP LOGISTICS

PEP logistics planning and implementation will be developed to be compatible with the basic STS logistics system. All logistics activities will use existing facilities, resources, and manpower wherever possible.

PEP will use standard integrated logistics support approaches, following the guidelines of JSC 07700 Vol. XII; they are shown in Figure 11.

The PEP Operations and Logistics Plan will be developed to describe the approach and implementation of the PEP logistics effort. The logistics program will be initiated with support requirement analysis, optimum repair level analysis, and maintainability analyses of the PEP design. Then a maintenance concept will be defined from which repair policies and a maintenance plan are derived. Subsequently, spares provisioning and consumable forecast data are generated.

Additional effort in developing operation and maintenance documentation; a packaging, handling, storage, and transportation program; and a training program will complete the logistics effort for the analysis and planning phase of PEP.

In the implementation phase, the contractor will produce the operation and maintenance documentation and activate logistics plan activities at KSC. Supply support, intermediate maintenance support, and training support will be done with KSC direction.

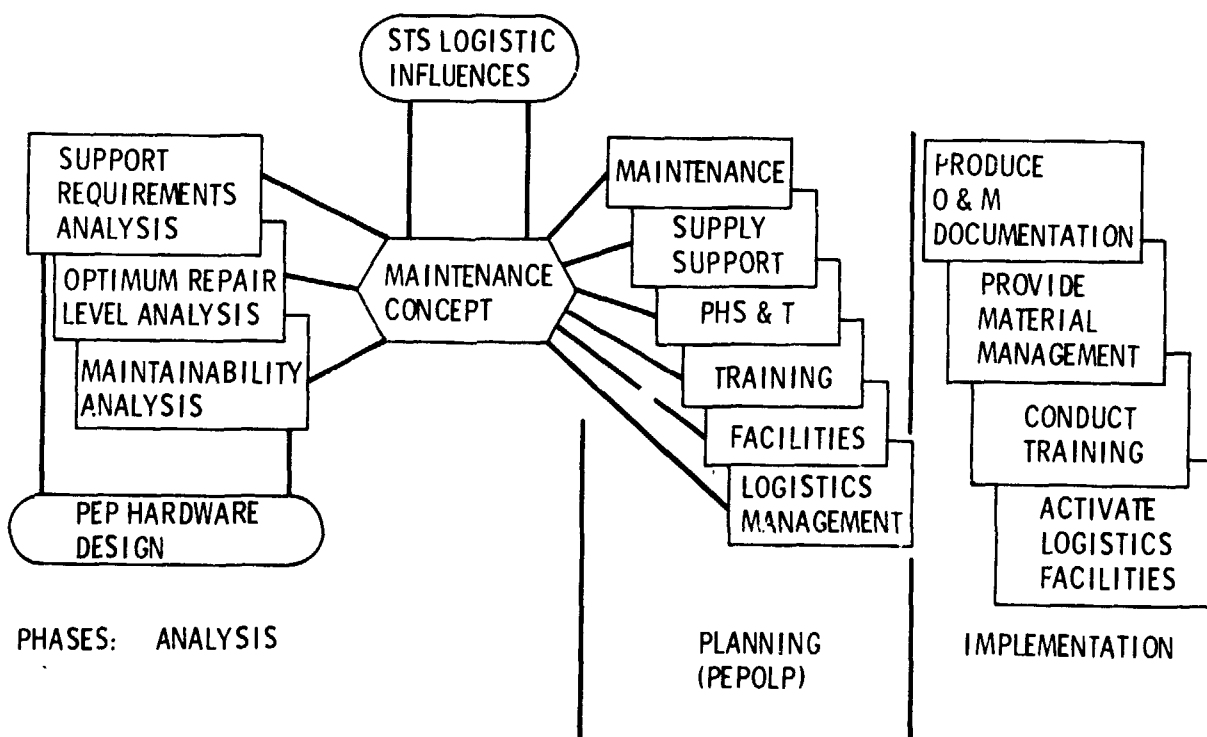


Figure 11. PEP Logistics

## 5.6 PEP MISSION GROUND AND FLIGHT OPERATIONS

Figure 12 is a pictorial flow of the PEP processing activities required at the KSC launch site facility and on-orbit activities. The dark arrows depict the activities flow for turnaround on subsequent flights. Horizontal processing and integration were baselined for the PEP with integration in the Orbiter occurring in the Orbiter processing facility (OPF).

During its orbital stay, the PEP will be deployed with the RMS arm to provide the power level and duration needed by the payload. The PEP will be stowed during orbital changes that require firing of the Orbital Maneuvering System (OMS) or when the RMS is needed for other payload activities. During return from orbit, the PEP will again be quiescent.

### 5.6.1 Launch Site Operations

Upon arrival at KSC, the PEP total system will be checked to verify successful Orbiter integration and subsystem compatibility. Depth of testing will be based on a modified ship-and-shoot philosophy for minimum KSC checkout effort. Cargo integration and test equipment (CITE) will be tested with other cargo

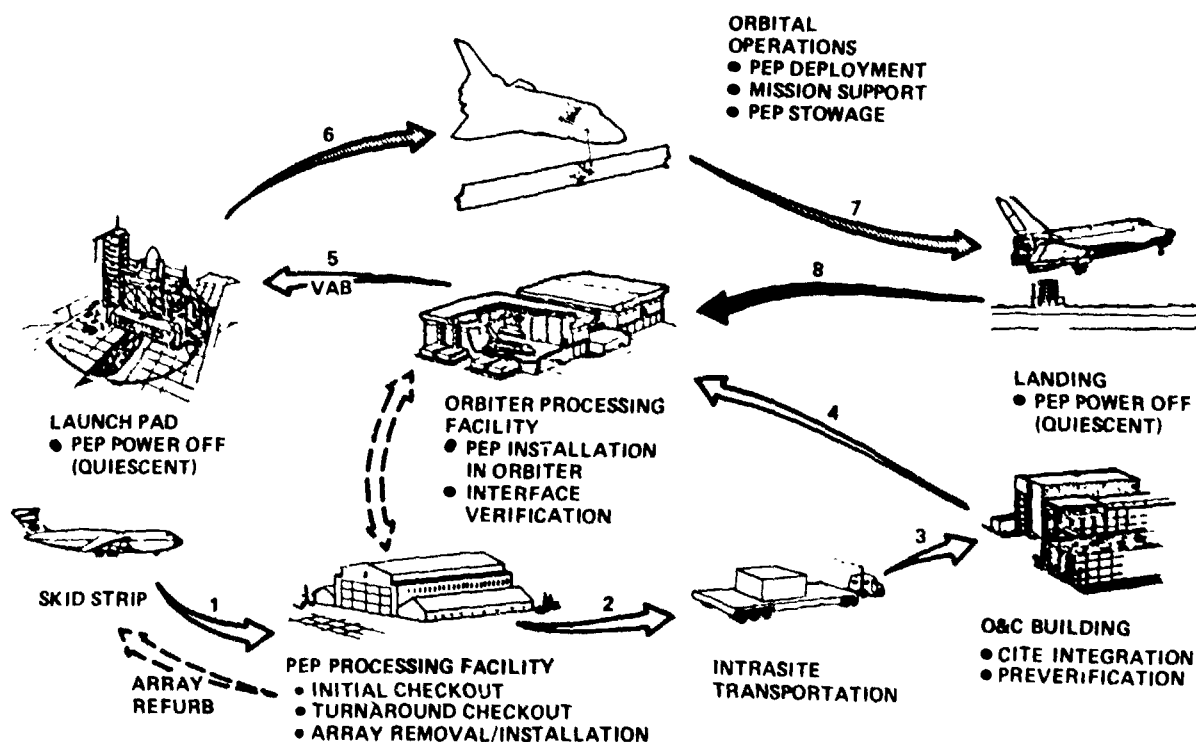


Figure 12. PEP Operations



elements and an Orbiter simulator before the first flight. CITE activities for subsequent PEP flights will be on an "as-needed" basis determined by other payload needs.

The critical launch processing activities are PEP installation and removal from the Orbiter in the OPF. For Spacelab module flights, the PEP will have to be installed after and removed before the tunnel since the PEP will be located directly over it. The GSE strongback will be used for simultaneous horizontal installation of the PEP hardware assemblies (i.e., ADA and PRCA) into the Orbiter payload bay. Installation and verifications will be performed without any serial schedule impact to the Orbiter. PEP power will be off until the PEP is deployed on orbit. Removal of the PEP in the OPF after the Orbiter lands will require only 13 hours. PEP can be removed from the Orbiter cargo bay at the launch (i.e., vertical) during contingency operations.

In the normal operational turnaround, after the PEP is removed from the Orbiter in its container, it will be transported on a flat-bed trailer to Hangar S and installed in the PEP test fixture. Its subsystems will be checked out, followed by an integrated systems and mission simulation test in which the solar arrays are not deployed.

Extended turnarounds will be required until the PEP becomes operational, and for solar panel maintenance (about every 2,000 hours of exposure). The extended turnarounds are the same except that the solar arrays will be removed from the PEP, returned to the factory for maintenance and checkout, and then returned to the launch site. Simultaneously with those activities, the remaining PEP subsystems will be checked out. After the solar arrays are reintegrated with the PEP, interfaces will be verified and an integrated systems test will be performed.

#### 5.6.2 Flight-On-Orbit Operations

PEP consists primarily of an electrical power subsystem comprising a deployable solar array and PRCA equipment. It will be installed in the cargo bay of the Orbiter as additional power demands dictate. The PEP system is transported to orbit while stowed in the Orbiter bay (it usually is mounted over the short tunnel on a Spacelab mission). However, it may be located anywhere along the length of the Orbiter bay within the RMS reach limits to accommodate specific mission requirements. On orbit, the solar array portion is attached to the Orbiter RMS and deployed.

Deployment is accomplished by the RMS operator from the aft flight deck while viewing from Orbiter windows and closed-circuit TV. During this placement, the PEP array is manually oriented toward the sun. At the operational position, the RMS is locked in place, the solar array is extended, and the PEP array provides power to the Orbiter. PEP is then in a functional mode.

During the mission, the array is oriented toward the sun using PEP gimbals controlled by a sun sensor. The RMS remains fixed with respect to the Orbiter. Power from the array is controlled through the PEP regulator while in the sun and the Orbiter fuel cells provide Orbiter/payload power during the dark portion of the orbit.

To stow the PEP, the solar array is retracted and the RMS activated. The operator guides the PEP until the PEP can be latched into its stowage position in the Orbiter bay.

Flight data will be acquired and formatted in the GPC. The data is transferred to the PCM system and transmitted to the ground via the tracking and data relay satellite system. The data is then transferred to mission control at JSC by the ground line or domestic satellite. Mission critical data will be decommutated and processed on standard Orbiter data processing equipment. Additional PEP flight data may be recorded during flight and processed on the ground during postflight analysis.

Section 6  
MANAGEMENT

TBD by JSC



Section 7  
PROCUREMENT APPROACH

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Section 8  
PROJECT DEFINITION ITEMS AND SCHEDULE  
(WBS, GFE LIST, MAJOR MILESTONES AND MASTER SCHEDULE,  
DELIVERABLE HARDWARE LIST, AND PLANS AND SPECIFICATIONS)

This section provides summaries of the basic project definition items which have been developed from programmatic analyses during this study phase and represent the framework for implementing the PEP hardware development and initial operations phases of the PEP Project. The WBS structure and level of elements and the master schedule and major milestones are provided from which the Phase C/D detail planning can be derived and controlled. Also included are the GFE and deliverable hardware lists. The GFE list represents the existing NASA equipment, which is assumed to be available to the PEP Project for future use. This equipment represents a previous NASA investment designated for reuse, which avoids what otherwise would be new costs chargeable to the PEP Project. The deliverable hardware list includes items to be delivered by the PEP system contractor as well as the Orbiter and RMS accommodations peculiar to PEP. This section also includes a summary of the plans and specifications which will be implemented as part of Phase C/D.

8.1 WORK BREAKDOWN STRUCTURE

This section provides the WBS for the PEP project. It shows the relationship of the PEP project to the STS program along with providing detail through Level 6 elements.

Figure 13 depicts the program WBS by the major elements. As indicated, the PEP Project is shown as a Level 3 project of the overall STS program. Level 3 PEP Project implementation would be through the designated Project Office. The project WBS Level 4 elements are organized similar to other STS program-related projects and represent the major elements of this project, including prime, associate, and NASA civil service and support contractor elements.

WBS Element 01, Orbiter Accommodations, provides for Orbiter integration support and Orbiter accommodations assumed to be done by the Orbiter contractor.

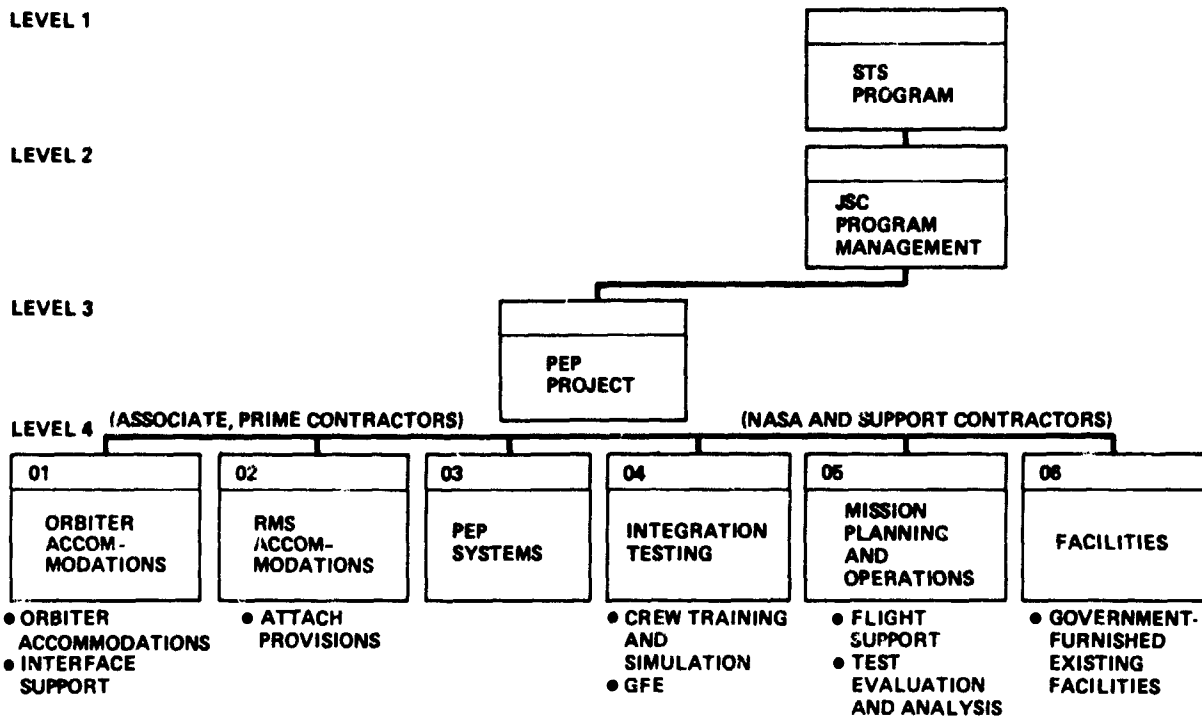


Figure 13. PEP Project Elements -- Summary Work Breakdown Structure

WBS Element 02, RMS Accommodations, provides for the modifications to be made to the basic RMS, consisting of the attach provisions necessary for installation of the PEP RMS cable assembly.

WBS Element 03, PEP System, provides for the DDT&E, production, and initial operations support through first flight of the PEP hardware, including the solar array. This element represents the PEP prime contractor and solar array subcontractor scope of work and represents the new hardware being developed.

WBS Element 04, Integration Testing, and 05, Mission Planning and Operations, provide for the PEP-peculiar NASA civil service and support contractor activities of integration testing and mission planning and operations at JSC and KSC. These elements will be expanded by JSC.

WBS Element 06, Facilities, provides for the facilities required for PEP other than contractor facilities. It is assumed that existing Government facilities at JSC and KSC will be made available and are believed to be essentially adequate. Any minor modifications, if required and identified as PEP-peculiar, would be included herein.

Figure 14 depicts Levels 5 and 6 for WBS Element 03, PEP System. Level 5 represents the system-level elements. Level 5, Flight Hardware element, is further broken down into Level 6 end-item elements. Lower-level WBS elements will be defined by the contractor as part of the Phase C/D proposal and approved by JSC during the initial project implementation period.

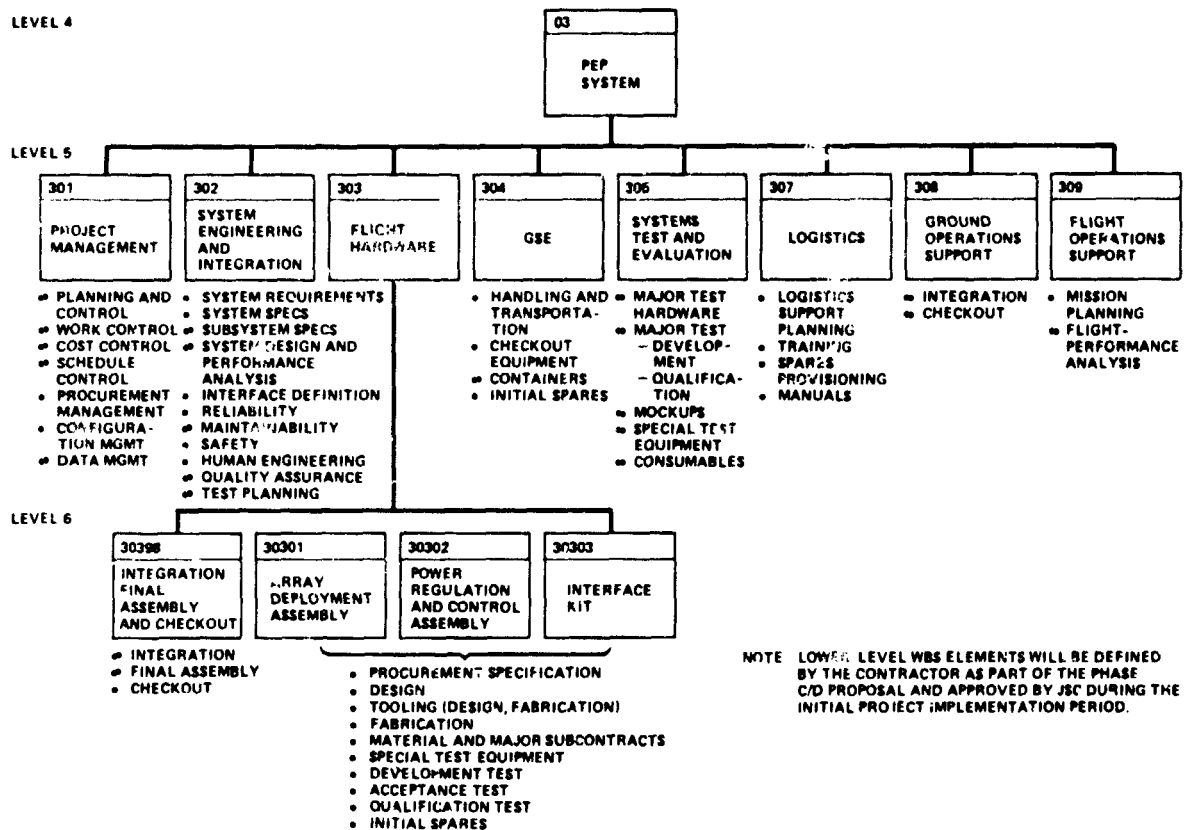


Figure 14. PEP WBS Elements

## 8.2 GFE LIST

The following GFE items have been identified and are planned to be available to the PEP Project for Phase C/D implementation and operations.

		Quantity
Apollo Program	Thermal conditioning unit S14-125 (G16-828610)	2
STS Program	RMS	2
	Beta cloth for RMS cable assembly shield	2

### 8.3 MAJOR MILESTONES AND MASTER SCHEDULE

This section contains a description and summary analysis of the PEP hardware development schedule. It is designed to provide a general understanding of the schedule logic, identify principal critical paths and discuss the relationship of the development plan to the PEP major milestones.

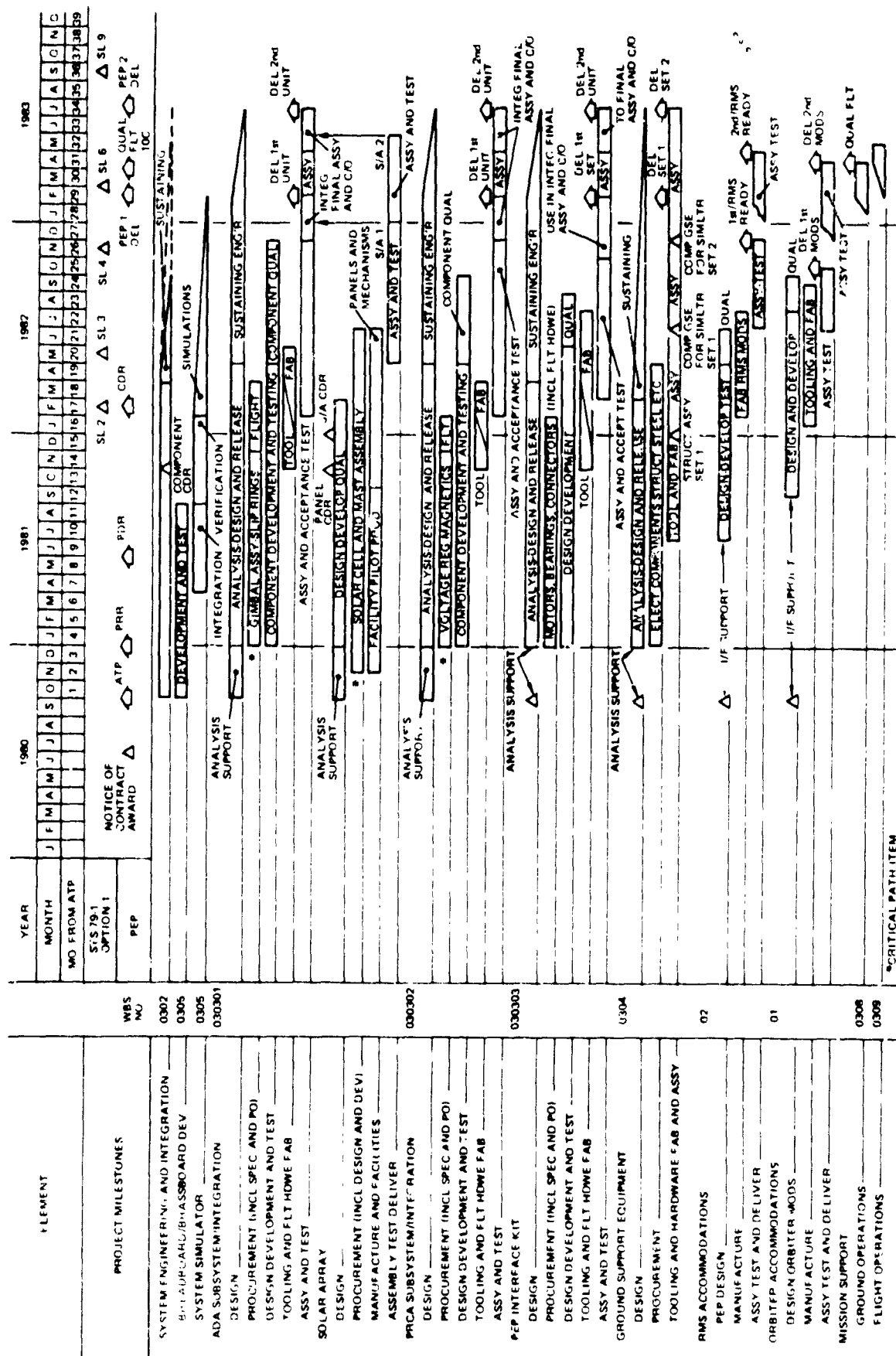
The PEP Project master schedule, Figure 15, has been structured in concert with the segregation of work displayed on the WBS, Figures 13 and 14. This correlation with the WBS provides a direct relationship between cost and schedule.

As shown on the schedule, a 30-month period is planned from project ATP to IOC. This time period is considered the shortest practical period in which to accomplish project objectives. The schedule is keyed to having PEP available for launch by the end of March 1983. To meet this schedule objective, 16 months has been allotted for accomplishing activities associated with Preliminary Requirements Review (PRR), Preliminary Design Review (PDR), and Critical Design Review (CDR). Accomplishment of these events within this time period will require timely and clear agreement on the design concept that is adopted.

Engineering development, analysis, and evaluation must be completed early in the project related to the long-lead items. Solar array design and procurement activity is planned to be initiated concurrently with the PEP contractor system design. The PRR results must be mutually definitive and acceptable and allow for early and parallel commitments for long-lead procurement of items such as solar cells by the solar array contractor and voltage regulators, electrical components, and gimbal components by the PEP contractor. It is assumed that planned pre-ATP activities will provide the necessary system definition to facilitate placement of purchase orders on these long-lead items in parallel with PRR.

Design reviews at the component level, as appropriate, will allow the release of engineering drawings required to design and fabricate tooling and begin the fabrication of detail parts in parallel with preparation for system-level design reviews, e.g., CDR. This approach will also allow early manufacture of parts for prototype hardware buildup and test to verify flight hardware design. Breadboard/brassboard development will begin at ATP, which will permit





an early start of integration/verification simulator operations for electrical development of the PEP system 6 months after ATP.

Qualification and flight hardware assembly will in most instances commence immediately following CDR. Thorough qualification testing and subsequent use of flight configuration components and GSE in the integration/ verification simulator will reduce or eliminate any incompatibilities during Orbiter interface tests at KSC. Also, Orbiter/crew safety during launch and landing and during in-flight deployment of the PEP system would be enhanced. The PEP/ solar array, PEP/RMS and PEP/Orbiter interfaces will be verified prior to hardware delivery to KSC. This testing will begin 2-1/2 months prior to delivery of the PEP system to the launch facility.

Final delivery of the PEP system will consist of two major end items plus the interface kit and GSE. The ADA, which includes the solar array, and the PRCA are the two end items. The RMS and Orbiter accommodations will be completed and available for delivery of the launch facility in parallel with the arrival of the PEP system.

KSC ground operations for preparing PEP for its first flight are scheduled for 6 weeks, including receiving, integration, checkout, Orbiter installation, and launch preparations.

#### 8.4 CRITICAL PATH ASSESSMENT

Three critical path items are identified on the schedule, consisting of the solar cell assembly, the voltage regulator, and the gimbal assembly components. In each instance, the principal critical issue relates to procurement leadtimes. The procurement of long-lead items, the manufacture and assembly of selected components for qualification to ensure qualified flight hardware and the subsequent integration, and final assembly and checkout of the PEP system are the critical paths that will bear constant and effective management if the project objectives are to be attained.

Project elements will be further analyzed and definitized during the Phase C/D proposal activity. Schedule logic and hardware leadtimes will be validated and revised, as appropriate, consistent with expanded definition. Schedules will be developed at lower levels during the C/D phase in keeping with expansion of the WBS to implement and validate the master schedule.

## 8.5 DELIVERABLE HARDWARE LIST

The following deliverable hardware items will be provided as the output of the design development and production phases of the PEP Project:

### I. PEP System Hardware

<u>Item</u>	<u>Quantity</u>
ADA	2
PRCA	2
Interface kit	2
GSE	2 sets
Initial spares	1 set

### II. Orbiter Accommodations

<u>Item</u>	<u>Quantity</u>
Structural/mechanical I/F provisions	2 sets
Electrical I/F provisions	2 sets
Thermal I/F provisions	2 sets

### III. RMS Accommodations

<u>Item</u>	<u>Quantity</u>
*RMS with accommodation Provisions	2

\*Basic RMS provided as GFE

## 8.6 PLANS AND SPECIFICATIONS

This section summarizes the Phase C/D plans and specifications for implementing the PEP Project. The plan tree and the design documentation structure for the documents are included, with a brief description of each and DRD numbers as applicable. Additional information on the requirements of each document is in Volume 12, PEP Data Item Descriptions.

### 8.6.1 Project Plans

Appropriate management, engineering, and operations planning and implementation are necessary to assure an integrated and controlled PEP Project. The plan structure for PEP is given in Figure 16. At the top level is the PEP Project Plan, supplied by NASA, which forms the basis for all other plans. The

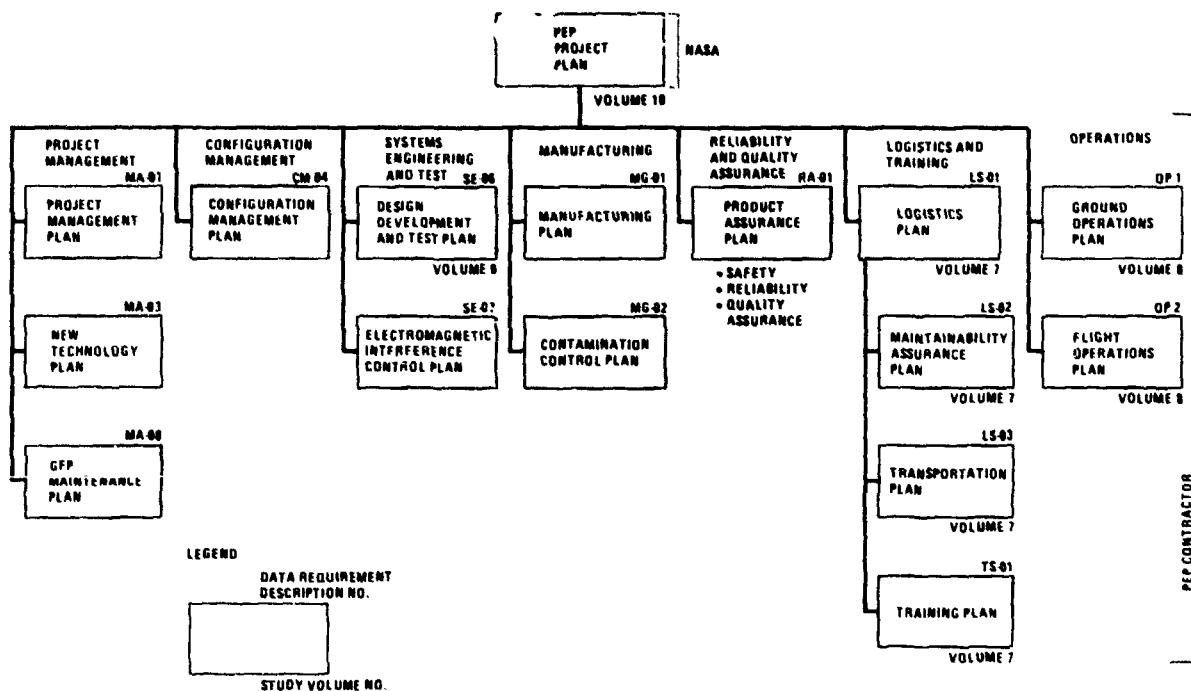


Figure 16. PEP Plan Tree

figure provides the following information:

- Identity of all plans to be prepared and/or updated by the contractor during Phase C/D.
- Relationship of each plan to the data requirement description line item number in Volume 12 of the extension phase of the Orbital Service Module Systems Analysis Study (OSMSAS).
- Relationship of each plan to the appropriate OSMSAS volume where a plan, or detailed requirements for a plan, was prepared during the Phase B effort.

Table 3 provides a summary of the purpose and scope for each plan listed in Figure 16.

#### 8.6.2 Specifications and Related Documents

The PEP design document structure is given in Figure 17. The Phase B study product (system specification, environmental specification, and interface definition document) represents the technical starting position for Phase C/D. As the design effort progresses during Phase C/D, these documents are refined by the PEP system contractor to contain the systems-level design and interface

Table 3. PEP Project Plans (Page 1 of 7)

I. NASA level	Purpose	Scope
PEP Project Plan	Provides the overall plan for developing and placing into operation the PEP as an element of the Space Transportation System program	<p>Contains summary of:</p> <p>Schedule and cost</p> <p>Project and mission objectives</p> <p>Related studies and technology support activities</p> <p>Management approach</p> <p>Procurement approach</p> <p>Project definition items and schedule (WBS, GFE list, deliverable hardware list)</p> <p>Resources</p> <p>Product assurance</p>
II. Contractor level	Purpose	Scope
Project Management Plan	To provide a description of the Contractor's methods for accomplishing the project requirements	<p>The plan contains an index of Contractor's internal operation plan, directives, and procedures (with brief discussion) covering:</p> <p>Project management</p> <p>Engineering management</p> <p>Manufacturing management</p> <p>Performance management</p> <p>Information management</p> <p>GFP management</p> <p>Procurement management</p> <p>Quality assurance management</p> <p>Configuration management</p>

Table 3. PEP Project Plans (Page 2 of 7)

II. Contractor level	Purpose	Scope
New Technology Plan	To provide a plan for the evaluation of technical work to identify presence of inventions and new innovations for patent purposes	<p>The plan contains the Contractor's approach to:</p> <p>Management concept to report new technology</p> <p>Early identification of new technology</p> <p>Exercising control over subcontractor compliance</p>
Government Furnished Property Maintenance Plan	To describe the method for controlling and maintaining Government furnished equipment	<p>The plan satisfies the requirements of NASA procurement regulation Appendix B and consists of those procedures which constitute the Contractor's property management manual</p>
Configuration Management Plan	To describe the Contractor's organization as it relates to configuration management, the procedures for identifying and documenting the configuration items, and the method of controlling changes	<p>The plan contains:</p> <p>Organization description</p> <p>Method for identifying baseline</p> <p>Control methods, procedures, and policies</p> <p>Accounting system description</p> <p>Verification system description</p> <p>Method for subcontractor/vendor configuration management control</p> <p>Plan for conducting/supporting project reviews</p>

Table 3. PEP Project Plans (Page 3 of 7)

II. Contractor level	Purpose	Scope
Design, Development, and Test Plan	Provides the plan to design, develop, qualify and produce the PEP and support equipment for testing and launch operations	Discusses: System definition and requirements Produce assurance Manufacturing plan Verification test and evaluation plan Integration and checkout plan Facilities and support equipment
Electromagnetic Interference Control Plan	To define the program for EMI control	The plan contains description of: Management controls EMI organization size, authority, organizational location, and responsibilities Prediction studies Breadboard tests Design reviews Circuit parameters for EMI computer program Electrical bonding Lightning studies Wiring controls Circuit return isolation
Manufacturing Plan	To define manufacturing methods and requirements	The plan contains description of manufacturing: Planning and control Processes and techniques Assembly sequence and techniques Operations safety Tooling approach Parts and materials management and handling

Table 3. PEP Project Plans (Page 4 of 7)

II. Contractor level	Purpose	Scope
Contamination Control Plan	To describe the system for contamination control	Facilities requirements and utilization
		Facility and tool activation planning and control
		Handling and control of end items
		Test and post manufacturing checkout
		Activation schedule
		This plan contains:
		Procedure for controlling manufacturing/assembly residues
		Description of controlled environments to be used during manufacture
		Procedures for cleaning and cleanliness verification
		Description of cleanliness verification techniques
Product Assurance Plan	Describes the Safety Plan for:	In accordance with NHB 5300.4 (ID-1), Chapter 2
	Establishing PEP safety criteria/requirements	
	Integrating these criteria/requirements into the PEP and Orbiter programs	
	Describes the Reliability Plan for:	In accordance with NHB 5300.4 (ID-1), Chapter 3
	Establishing PEP reliability criteria/requirements	
	Integrating these criteria/requirements into the PEP and Orbiter programs	



Table 3. PEP Project Plans (Page 5 of 7)

II. Contractor level	Purpose	Scope
	Describes the Quality Assurance Plan for verifying that the PEP and GSE satisfies Section 3, "Requirements" or their respective specifications	In accordance with NHB 5300.4 (ID-1), Chapter 5
Logistics Plan	To provide an Implementation Plan covering all logistics functions necessary to support PEP integration, prelaunch, launch, flight, and postlanding operations	<p>The plan identifies the Contractor's planning for products and services required to implement:</p> <ul style="list-style-type: none"> <li>Support requirements analyses</li> <li>Optimum repair level analyses</li> <li>Maintainability</li> <li>Maintenance</li> <li>Spares provisioning</li> <li>Fuels, pressurants, and fluids</li> <li>Operations and maintenance documentation</li> <li>Pressurization, packaging, and packing</li> <li>Transportation</li> <li>Storage criteria</li> <li>Logistics management</li> <li>Training</li> <li>Logistics facilities</li> </ul>
Maintainability Assurance Plan	To define the Contractor's approach for maintainability of the PEP flight hardware and deliverable GSE	The plan defines the method of accomplishing maintainability requirements and describes how the requirements will be implemented. It describes the procedures, policies, and reporting system that will be used

Table 3. PEP Project Plans (Page 6 of 7)

II. Contractor level	Purpose	Scope
Transportation Plan	To aid in the identification of packaging, materials handling, and transportation requirements	<p>The plan contains:</p> <ul style="list-style-type: none"> <li>Packaging requirements</li> <li>Requirements to handle pressure and to pack and ship PEP flight hardware, associated support equipment, and spares</li> <li>Management organization</li> <li>Milestone chart</li> <li>Discussion of transportability problem areas</li> <li>Description of cargo requiring transportation</li> <li>Transportation restrictions</li> <li>Identification of regulatory agency approvals</li> <li>Description of special purpose carrier equipment and services</li> </ul>
Training Plan	To provide methods and procedures to be used to train personnel	<p>Each Training Plan contains identification of:</p> <ul style="list-style-type: none"> <li>Activities requiring training</li> <li>Training objectives and milestones</li> <li>Curriculum requirements</li> <li>Student population</li> <li>Methods of instruction</li> <li>Certification methods and requirements</li> <li>Training program evaluation</li> <li>Readiness measurement</li> <li>Training equipment</li> <li>Facilities</li> </ul>

Table 3. PEP Project Plans (Page 7 of 7)

II. Contractor level	Purpose	Scope
Ground Operations Plan	Describes the plan for the PEP ground processing operations at the ELS. The plan identifies groundrules philosophy and required launch site resources associated with PEP operations	Establishes the concepts and methods by which the PEP ground operations will be conducted at the ELS. Areas covered include:  Pep requirements and timelines  Prelaunch operations, both off-line and on-line  Postlanding operations including turnaround for next flight
Flight Operations Plan	Describes the plan to assure that PEP is operational on orbit and that these operations:  are compatible with those of Orbiter  are integrated with those of Orbiter	Discusses:  Operations timelines  Flight operations displays and controls  Contingency operations  Simulations  Requirements for flight operations plan  Qualification flight plan  Crew training  Launch operations  Orbital operations  Instrumentation/monitoring  Extravehicular activity  Contingency operations  Postflight analysis

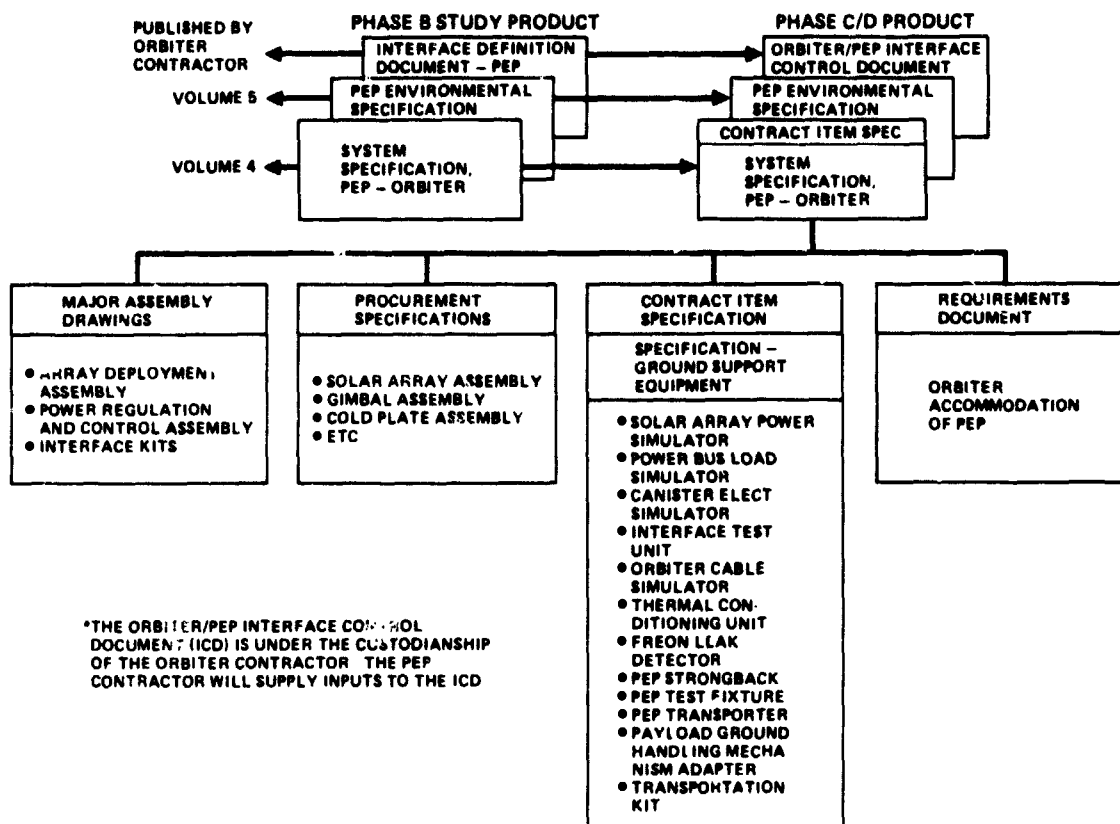


Figure 17. Top-Level PEP Design Document Structure

requirements. The PEP contractor is responsible for the updates and refinements to the PEP-Orbiter system specification and the related environmental specification. The Orbiter/PEP interface control document is under the custodianship of the Orbiter contractor. This document will be developed jointly by Orbiter and PEP contractors.

As shown, the next level of documentation is composed of:

- Major assembly drawings.
- Procurement specifications.
- GSE specification.
- Requirements document for Orbiter software and hardware.

The Orbiter software and hardware requirements document is prepared by the PEP contractor. It is intended that this document be approved by NASA and implemented with the Orbiter contractor. This document serves the same purpose as the system specification with the PEP contractor.

Table 4 lists all the Phase C/D documents identified and summarizes their purpose, preparation instructions, and applicable data item description line item number from Volume 12.

Table 4. PEP Design Document Structure (Page 1 of 2)

Document	Purpose	Data reqmt. description line item no. (see Volume 12)
System Specification, PEP-Orbiter	To define the functional, performance, design, and test requirements for the PEP System and its associated ground support equipment	CM-10
PEP Environmental Specification	To establish the natural and induced environments to which the PEP and its GSE may be exposed during ground operations and spare operations with the Shuttle system	CM-12
Orbiter/PEP Interface Control Document	<p>To depict physical and functional interface engineering requirements of an item that affects the design or operation of cofunctioning items; i.e., Orbiter and PEP. The document:</p> <p>Establishes and maintains compatibility between Orbiter and PEP</p> <p>Controls interface designs</p> <p>Communicates design decisions and changes</p> <p>Establishes envelope and access compatibility</p>	Orbiter contractor custodial responsibility. PEP contractor to participate
Assembly drawings	To depict the assembled relationship of each of the three assemblies listed.	SE-01
ADA		
PRCA	It contains sufficient views to show the relationship between each subordinate assembly and part comprising the part depicted	
Interface kits		

Table 4. PEP Design Document Structure (Page 2 of 2)

Document	Purpose	Data reqmt. description line item no. (see Volume 12)
Procurement specifications	<p>These will be of two types: development specifications and/or product specifications, depending upon whether develop- ment effort is required</p> <p>Development specification: to define the functional require- ments for each configuration item</p> <p>Product specification: to provide a document adequate for the procurement, production, test, evaluation, and accep- tance of an item without requiring further development work</p>	Not applicable
Specification-ground support equipment	To establish in one document the performance, design, development, and test requirements for all ground support equipment	CM-12
Requirements documents- Orbiter software and hardware	To define the hardware and software performance and design requirements that should be imposed on the Orbiter system for accomo- dation and utilization of the PEP system	SE-11

## Section 9 RESOURCES

This section provides the total project cost and manpower estimates by year and total for all project elements, covering design development, production, operations, and support. NASA in-house civil service and support contractor estimates are yet to be determined and will be generated by JSC. Also included is a discussion of the facility aspects which indicate that PEP needs can be met with existing contractor and Government facilities, and with facilities being prepared by the prospective solar array contractor(s) which will be available by ATP.

The basis of the cost and manpower estimates is summarized in Volume 11, PEP Cost, Schedules, and WBS Dictionary.

### 9.1 PROJECT ESTIMATED COST

The cost estimates for the PEP project are summarized in Table 5. Each line item is listed separately, including WBS element name, WBS number(s), and annual and total runout funding in real-year dollars. The upper portion of the table shows the funding required for the prime, associate, and subcontractors, which represents the basic costs of providing hardware. The lower portion of the table, which is TBD, introduces the civil service and support contractor elements which represent the total estimated cost of the PEP project.

The following groundrules reflect the major aspects from which the costs were derived:

- A. Costs were estimated in 1978 dollars and escalated to real-year dollars using a 7% escalation rate provided by JSC.
- B. Costs exclude prime and solar array subcontractor fees.
- C. Costs include two sets of PEP hardware and modification of two Orbiters and two RMS's.
- D. Costs include operations support through IOC.
- E. Orbiter accommodation costs were provided by JSC.

The costing methodology for the PEP system included parametric estimating, direct estimating, and vendor quotes. The Orbiter accommodations costs were analyzed and provided by JSC. RMS accommodations costs were estimated and provided by the RMS contractor.

As can be seen in Table 5, the funding requirement for the PEP system is \$81.7M, including \$38.8M for the solar array. The Orbiter accommodation funding is \$6.0M and the RMS accommodations (scars to attach the cable assembly) funding is \$.9M. The total hardware contractor's funding is \$88.6M to deliver the hardware and provide support through IOC. Support contractor funding is shown as TBD and will be determined by JSC.

This funding plan reflects a relatively modest FY 81 funding of \$12M with substantial funding not required until FY 82 and 83, consistent with the offloading of funding from the basic Shuttle development program.

## 9.2 PROJECT MANPOWER REQUIREMENTS

The manpower estimates for the PEP Project are summarized in Table 6. The estimates are consistent with the cost estimates reflected in Table 5 and shown in the same format. As was stated in Section 9.1, the in-house civil service and support contractor manpower estimates are D and will be developed by JSC.

As stated in Section 9.1, the basic estimating during this study employed parametric and direct estimating techniques and vendor quotes. The manpower estimates were then derived from direct estimates and by splitting the parametric dollar estimates into labor and non-labor, based on historical data for the type of WBS element involved, and then calculating the number of direct labor man-years which correspond to the labor dollar estimates. These man-years were then summarized and evaluated for balance, and are shown in Table 6. During the proposal phase more detailed direct manpower estimates will be introduced and the results incorporated as an update of this plan. It is felt that the current manpower estimates are representative and appropriate for Phase C/D planning.



Table 5. PEP Project Costs  
(In Real-Year \$M)

Elements	WBS No.	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	Total
PEP system (excluding solar array)	03			5.6	23.3	14.0	--	42.9
Solar array				5.5	21.1	12.2	--	38.8
Total PEP system				11.1	44.4	26.2	--	81.7
Orbiter accommodations	01			0.9	4.3	0.8		6.0
RMS accommodations	02			0.1	0.4	0.4		0.9
Total prime/associates/ subcontractor				12.1	49.1	27.4	--	88.6
*Integration testing	04							
*Mission planning and operations	05							
*Total NASA and support contractors								
*TBD by JSC								

Table 6. PEP Project Manpower  
(In Man-Years)

Elements	WBS No.	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	Total
PEP system (excluding solar array)	03			61	180	149		390
Solar array				50	165	61		276
Total PEP system				111	345	210		666
Orbiter accommodations	01			12	47	7		66
RMS accommodations	02			1	4	4		9
Total prime/associates/ subcontractor				124	396	221		741
*Integration testing	04							
*Mission planning and operations	05							
*Total NASA and support contractors								
*TBD by JSC								

### 9.3 FACILITY RESOURCES

As is discussed in Section 5.4, prime contractor and NASA facilities are adequate and will be made available as planned. Also, as noted previously, existing facilities of prospective solar array subcontractors are in the process of being augmented and will be available for PEP by ATP. Therefore, it is not anticipated that expenses for new facilities or facility modifications will be required for PEP.

Section 10  
MANAGEMENT REVIEW

Project management will review the project with agency management during project implementation. The reviews will normally be scheduled to be held upon completion of significant project events. They will take place after the corresponding event has been completed between the NASA project management and the contractors. Six reviews have been identified and scheduled:

- Project Requirements Review (PRR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Pre-Ship Review (PSR)
- First Flight Readiness Review (FRR)
- Initial Operational Capability (IOC)

Project-level reviews between NASA project management and the contractors will be held in accordance with the events indicated above. In addition, monthly and quarterly progress meetings will be held throughout the development phase except for the months in which the above major events are scheduled. As part of these reviews, the first definitive total cost estimate at completion (EAC) for project development will be established upon completion of the PDR. By then, the project requirements will have been translated into a preliminary design which satisfies those requirements with NASA project office concurrence. The EAC will then be updated periodically as detail design and manufacturing proceed through hardware delivery. These EAC's will be the basis for annual budget planning inputs to agency management.

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Section 11  
CONTROLLED ITEMS

The specified controlled items require approval at NASA senior management levels before they can be changed. Some items will be controlled by the administrator or his designee in the project approval document, some by the Program Associate Administrator, and some by the Program Director, as determined by NASA. A candidate list of controlled items follows for NASA consideration:

- PEP mission objectives and requirements.
- Mission flight assignments.
- Total estimated project cost at completion.
- PRR, PDR, and CDR review dates.
- Hardware delivery dates.
- First flight and IOC date(s).

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Section 12  
SAFETY, RELIABILITY, AND QUALITY ASSURANCE

Safety, Reliability, and Quality Assurance planning will be accomplished early in the PEP development process, consistent with NASA program requirements, to assure the development, manufacture, and delivery of a safe, reliable product of high quality. Planned activities will span the establishment of requirements and their implementation and verification through PEP development, manufacture, test, and operations.

12.1 SAFETY

PEP safety requirements will be made compatible with STS requirements through established formal contractor procedures that meet NASA requisites. STS and PEP personnel and equipment safety will be assured by design and procedural provisions and will be verified through analyses and inspection.

Safety program planning and requirements will include safety analysis activities for the design development, and facility safety provisions to assure personnel and equipment fabrication and operational safety. Planned activities will include the following:

- Establishment and implementation of safety criteria in design provisions and procedures development.
- Performance of hazard analyses and the provision of controls for those hazards which cannot be eliminated.
- Establishment of requirements and provisions for handling, storage, servicing, and transportation safety.
- Establishment of requirements and provisions for facilities and support safety.
- Establishment of an industrial safety program.

In addition to the above contractor safety features and activities, the launch site operations and flight operations will be analyzed, approved, and monitored by NASA safety personnel to assure the safety of ground and flight personnel and hardware.

12.2 RELIABILITY

PEP system reliability requirements will be developed through design cost optimization trade studies and will be established through formal contractor

procedures which satisfy NASA requirements. PEP reliability will be developed in consonance with the STS program requirements for payload and supporting systems.

PEP system reliability requirements will be applied to the subsystems and components in a logical manner consistent with the design process and within the state of the art. Design criteria will be established and implemented to assure the attainment of the reliability design requirements. Primary criteria will include design margins, derating factors, redundancy backup, and other failure correction and safing techniques. Numerical reliability goals and apportionments will not be used.

Assurance that the reliability requirements are achieved will be provided through design reviews and reliability assessment activities. Specific analyses that will be performed include:

- Failure modes and effects analysis.
- Derating and part stress analysis.
- Mechanical stress analysis.

Results of the analyses will be presented at the formal NASA and contractor design reviews.

### 12.3 QUALITY ASSURANCE

Quality assurance will be performed by contractor personnel in accordance with established Company procedures that comply with NASA quality requirements. Where appropriate, Government or Company source inspection will be employed.

PEP quality assurance planning will address the following features:

- Identification of the resources required.
- Inspections of fabrication, assembly, and test operations.
- Controls implemented for precision measuring devices.
- Controls for the identification, reporting, and analysis of non-conforming articles and implementation of corrective actions.
- Controls imposed for handling, storage, and preservation of hardware and equipment.
- Validation of software quality.